PERFORMANCE AND CARBON SEQUESTRATION POTENTIAL OF TOP FEEDS UNDER VARIED PLANTING GEOMETRY

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KERALA, INDIA
2022

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by

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THESIS

Submitted in partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2022

DECLARATION

I, hereby declare that this thesis **"PERFORMANCE AND CARBON SEQUESTRATION POTENTIAL OF TOP FEEDS UNDER VARIED PLANTING GEOMETRY"** 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.

Vellayani

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CERTIFICATE

Certified that this thesis entitled **"PERFORMANCE AND CARBON SEQUESTRATION POTENTIAL OF TOP FEEDS UNDER VARIED PLANTING GEOMETRY"** is a record of research work done independently by Ms. Mubeena P. (2018-21-051) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ACKNOWLEDGEMENT

"Gratitude is the memory of the heart"

"Commit to the lord whatever you do and your plan will succeed". I start with the name of almighty, who is most beneficent and merciful. I am greatly thankful to God for giving me blessing and always illuminating me with the light of success.

I feel immense pleasure to express my profound and heartfelt gratitude to ***Dr. Usha C. Thomas****, Professor and Head, Instructional Farm, College of Agriculture, Vellayani and the Chairperson of my advisory committee for her guidance, lively encouragement, constructive criticism, support, unfailing patience and generous assistance at every stage of my research. I extend my sincere thanks for providing a stress free situation by the open minded approach and for the care and affection bestowed on me throughout the study period.*

I also consider it a great privilege to record my respect and indebtedness to ***Dr. Shalini Pillai P.,*** *Professor and Head, Department of Agronomy and member of advisory committee for her valuable suggestions, critical evaluation, technical advices and incessant motivation throughout the research work.*

I also express my sincere gratitude to ***Dr. Jacob John****, Professor and Head, ntegrated Farming System Research Station, Karamana & DE, KAU for his valuable guidance, helpful suggestions and advice rendered throughout the course work.*

I gratefully acknowledge with special thanks ***Dr. Aparna B.****, Professor and Head, Department of Organic Agriculture, for her constructive comments, creative suggestions and affectionate approach at all the stages of research work.*

I am pleased to thank ***Dr. Beena Thomas****, Assistant Professor, Department of plant breeding and genetics, College of Agriculture, Padannakkad and* ***Dr. Deepa Surendran,*** *Assistant Professor, Krishi Vigyan Kendra, Ambalavayal for their valuable guidance and helpful suggestions and advice rendered throughout the throughout the research work.*

I am grateful to ***Dr. O. Kumari Swadija*** *(Former Professor and Head, Department of Agronomy) for her inspiring guidance which enabled to do the best of my ability in bringing out this thesis. I also thank* ***Dr. Sansamma George*** *(Former Professor and Head, Department of Agronomy),* ***Dr. Elizabeth K Syriac*** *(Former Professor and Head, Department of Agronomy),* ***Dr. A. S. Anilkumar*** *(Former Professor and Head, Department of Agronomy) and* ***Dr. L. Girija Devi*** *(Former Professor and Head, Department of Agronomy) for their immense help, willingness and generous assistance at one stage or other of the research. I also express my immense gratitude to all teachers of Department of Agronomy.*

My special thanks to ***Dr. Anita M. R****., Farm Manager, AICRP on forage and AICRP on forage crops and utilization, College of Agriculture, Vellayani, for her precious advice and support during the course of study.*

I wish to remember and never forget in my life the company of affectionate ever Loving friends ***Dhanu chechi, Bincy, Shahlas, Pooja, Tharani and Athira G Menon*** *whose hands were evident at each and every moment of tension, anxiety and achievements.*

Words fall short to express special thanks to my classmates ***Limu, Vijay, Anit, Arunjith, Jince*** *and* ***Shahana*** *for their valuable guidance, love and support for my studies and writing unforgettable memories. I also express my sincere thanks to my* ***friends, Kiran, Ajay, Syam sankar, Greeshma, Deepthi, Navya, Althaf, Shibina, Ebi, Reshu, Suji, Adhi, Pooja P Gowda, Geethu, Gritta chechi, Dhanu Unnikrishnan, Arunima, Aparana, Namitha, Shreena, Shana, Deva, Vijeesh, Athulya, Jenny, Fasi*** *and* ***Hari*** *for their help, good company, positive criticism, unconditional love, care and moral support throughout my PhD programme.*

I express my deep sense of gratitude to my departmental non-teaching staff, ***Shibu chettan, Babitha chechi, Sumesh chettan, Sanal chettan*** *for the timely help and support rendered to me during both field and lab works.*

What I am today is because of the unconditional love and support of my dearest ***Amama,*** *beloved* ***Uppachi Mr. Muhammed Ismail, Ummachi Mrs. Zainaba,*** *my siblings* ***Abdul Basith, Mufeeda*** *and* ***Nida,*** *my niece* ***Dua,*** *my* ***uppa Mr. Usman, Umma Mrs. Shahla*** *whose sacrifices I can never repay. They inspired me in every step of my life, showed me to always take life one step at a time and never to give up even in the face of overwhelming odds.*

At last but not the least I am beholden beyond words to express my indebtedness to my love of life, Mr. ***Nadirsha Thottiyan*** *for his unconditional love, sacrifices and support bestowed on me during my hard periods.*

If any omission in this brief acknowledgement does not mean lack of gratitude.

MUBEENA P

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ATER	Area time equivalent ratio
BCR	Benefit cost ratio
BN	Bajra Napier hybrid
C	Carbon
Ca	Calcium
CD	Critical difference
CR	Competitive ratio
cm	Centimetre
cm^2	Square centimetre
C:N	Carbon : Nitrogen
DAS	Days after sowing
DMP	Dry matter production
dS m^{-1}	Deci Seimens per metre
EC	Electrical conductivity
EPS	Extracellular polymeric substances
et al.	Co-workers/ Co-authors
Fig.	Figure
Fe	Iron
FYM	Farmyard manure
g	Gram
ha	Hectare
ha^{-1}	Per hectare
i.e.	That is
K	Potassium
K_2O	Potassium oxide
KAU	Kerala Agricultural University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
kg ha^{-1} yr^{-1}	Kilogram per hectare per year
L	Litre
LER	Land Equivalent Ratio

L:S	Leaf Stem ratio
MAP	Month after planting
MAI	Monetary advantage index
Mg	Magnesium
mg g^{-1}	Milligram per gram
mg kg^{-1}	Milligram per kilogram
mm	Millimetre
Mn	Manganese
MOP	Muriate of Potash
N	Nitrogen
NO_3^-	Nitrate ion
No.	Number
NS	Not significant
P	Phosphorus
pH	Potenz Hydrogen
PoP	Package of Practices
P_2O_5	Phosphorus pentoxide
RBD	Randomized block design
S	Significant
S	Sulphur
Si	Silicon
₹ ha^{-1}	Rupees per ha
SEm	Standard error of means
t	Tonnes
t ha^{-1}	Tonnes per hectare
viz.	Namely
Vs.	Versus
Zn	Zinc

LIST OF SYMBOLS

%	Percent
@	At the rate
^{o}C	Degree Celsius
µ	Micro
₹	Rupees
^{0}E	Degree East
^{0}N	Degree North
±	Plus-minus sign

1. INTRODUCTION

Livestock production is the backbone of Indian agriculture and plays a key role in providing employment especially in rural areas. Fodders are a group of crops which differ from food and commercial crops as they are primarily grown for the fresh green vegetative biomass. India has 15 per cent of world cattle population and there is tremendous pressure of livestock on available feed and fodder, as land available for fodder production has been decreasing. Presently, it is estimated that only 4.4 per cent of the total cropped area is devoted to fodder production (GOI, 2019). Feed and fodder constitute about 60 to 70 per cent of cost of milk production (Meena *et al*., 2020), thus cultivated fodder plays an important role in meeting requirement of various nutrients and roughage in our country to produce milk most economically as compared to concentrates.

Dairy production is an important subsidiary and complimentary farming activity widely adopted in Kerala especially as a part of homestead farming system. The livestock census data from 1996 to 2012 showed a drastic reduction in cattle population (GOK, 2014). The major factor behind this reduction include scarcity of cheap and quality fodder, rapid increase in the price of feed and feed ingredients, diminishing grazing land and urbanization. Among these, availability of cheap and quality feed is a major issue. Considering the fodder crop production scenario in Kerala, the cultivated area under fodder in Kerala is only 5227 ha. The fodder requirement in the state is 232.0 mt whereas the availability is only 94.5 mt, with a deficit of approximately 60 per cent (137.5 mt) (GOK, 2020). The major reason behind the scarcity of fodder in Kerala may be due to fragmentation of land and shift in cropping pattern from food crops to cash crops.

Fodder trees and shrubs constitute a potential source of protein for ruminants in the tropics. But these feed resources have been generally ignored in feeding systems for ruminants, mainly because of inadequate knowledge on nutritional quality of fodder. In difficult environmental conditions, where the available grazing is not sufficient to meet the maintenance requirements of animals for part of the year, the contribution from trees and shrubs is significant. Tree fodders contain high levels of crude protein and minerals and many show high levels of digestibility. They are readily accepted by livestock and presumably because of their deep-root systems, they continue to produce well into the dry season. At the same time, there are certain anti-nutritional factors like oxalate, nitrate, tannin etc. present in fodder trees that interfere with feed utilization and affect animal health and reproduction.

Bajra Napier hybrid is an introduced fodder grass, which has gained popularity among dairy farmers, as compared to the other introduced grasses, this grass is well adapted to the agroclimatic situations of Kerala, because of its quick growth, palatability, high nutritive quality and herbage yield (Antony, 2012).

Agathi (*Sesbania grandiflora*) is a leguminous nitrogen fixing fodder tree that grows well under tropical warm humid climate, it is a rich source of various minerals and vitamins. The leaves contains 25-30 percent crude protein, 30 mg phosphorus, 184 mg potassium, 15 mg sodium and 9600 IU vitamin A in every 100 g and it is an important food supplement for cattle. The tree produces leaves for fodder within four months of establishment.

Fresh foliage of drumstick (*Moringa oleifera*) can be included into the diet of different animals and it is able to produce and maintain high biomass yields over the years. Annually, drumstick can produce more than 100-120 tonnes of green fodder per hectare in four to five cuttings, sufficient enough for feeding 18 to 20 animals under mixed feeding system (Mithare, 1995)

Erythrina (*Erythrina indica*) is a multipurpose tree, often used in agroforestry systems. It can be lopped for fodder, as its foliage has a relatively high protein content that makes it an excellent feed for most livestock. They help in maintaining soil moisture under their canopy and improve microbial activity. *Erythrina* as a fast growing nitrogen fixing legume particularly useful for soil enrichment. It nodulates readily and prolifically, in both acid and alkaline soils

Silvi-pastoral system with suitable species of trees and grasses help in increasing the land productivity and also maintain environmental potentialities. Moreover, deep root system of trees bind the soil, reduces erosion and extracts moisture from deeper strata of the soil. Apart from being a source of nitrogen supplement, tree legumes also reduce soil erosion, improve soil water conservation, suppress weed growth, replenish soil fertility and provide additional products such as fuel. Trees help in augmenting biodiversity, improve microclimate and support threatened soil micro flora and fauna, animals and birds providing them forage, feed and habitat.

Intercropping of top feeds with grasses provides many ecosystem services. Global climate change caused by rising levels of carbon dioxide (CO_2) and other greenhouse gases is recognized as a serious environmental issue of the twenty-first century. Between 2000 and 2010, the atmospheric CO_2 levels have increased from 369 to 388 mg kg^{-1}, a 5.1 per cent increase over the past 10 years (Turnbull *et al.*, 2011). It has been increasingly recognized that agroforestry practices such as silvopastural system has much importance in mitigating climate change effect because of high carbon storage potential (Nair and Nair 2003). Adapted tree-grass combinations can make a valuable contribution to forage production and carbon sequestration. But knowledge of the interaction effects between fodder trees and grasses on their production is limited. In this background the present study was undertaken with the following objectives.

- To standardize the optimum plant population for higher green forage yield, quality and carbon sequestration potential.
- To assess the performance of different plant species as top feeds under sole and intercropping system.
- To assess the quality of predominant fodder trees and shrubs of southern Kerala.

1. REVIEW OF LITERATURE

An experiment was entitled "Performance and carbon sequestration potential of top feeds under varied planting geometry" was conducted at College of Agriculture, Vellayani to standardize the optimum plant population for higher green forage yield, quality and carbon sequestration potential and to assess the performance of different plant species as top feeds under sole and intercropping system. The study also envisages to assess the quality of predominant fodder trees and shrubs of southern Kerala. The available studies that are directly or indirectly related to the topic of research from various sources are reviewed in this chapter.

2.1 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON BIOMETRIC AND YIELD ATTRIBUTES OF TOP FEEDS

2.1.1 Number of Branches

A study conducted by Rivest *et al*. (2010) reported that the number of branches of poplar tree increased by 1.5 times when it was intercropped with soybean. A study regarding effect of spacing and intercropping on the growth of *Jatropha curcas* was conducted by Subbulakshmi *et al.* (2019) and the result revealed that there was an increase in number of branches of the tree from 13.3 to 14.4 when it was intercropped with cow pea.

The study conducted by Karthikeyan *et al*. (2018) regarding compatibility studies of fodder crops with *Melia dubia* and observed that the number of branches of *Melia dubia* was increased in intercropping system than that of *Melia dubia* monocropping. They have also mentioned that *Melia dubia* + hedge lucerne intercropping system recorded significantly higher number of branches (6.25) than that of *Melia dubia* monocropping (5.79).

2.1.2 Leaf Stem Ratio

Among different spacing treatments, cassava with wider spacing of 1.5 m x 1.5 m recorded more leaf stem ratio than that of 0.8 m x 0.8 m spacing (Streck *et al*., 2014). A study conducted by Patric *et al*. (2020) on productivity of tree fodders in typical home garden of central Kerala found that leaf stem ratio of agathi was 1.09 and that of drumstick was 0.66.

2.1.3 Green Fodder Yield

Significantly higher green fodder yield of 3.85 t ha^{-1} was noticed by cowpea when it was intercropped with Guinea grass (Anita *et al*., 2011). Susheela *et al*. (2020) observed that significantly highest green fodder yield (508.93 q ha^{-1}) was obtained when subabul (*Leucaena leucocephala*) was intercropped with Bajra Napier hybrid (*Pennisetum glaucum* × *P. purpureum*) and desmanthus (*Desmanthus virgatus*). Murali *et al.* (2022) recorded significantly higher green fodder yield for sesbania when it was intercropped with Bajra Napier hybrid.

Thomas *et al.* (2021b) observed that among different agathi (*Sesbania grandiflora*) based fodder production systems, significantly higher green fodder yield of agathi was noticed when it was intercropped with rhodes grass under 2:2 row proportion (18.78 t ha^{-1}). However, intercropping agathi with congosignal grass under 2:2 row proportion recorded significantly lowest green fodder yield of 10.24 t ha^{-1}.

2.1.4 Dry Matter Yield

Mwangi (1999) showed higher total dry matter yield of Napier grass + legume intercrop than sole Napier grass. A study conducted by Raj *et al*. (2016) to assess the forage yield and nutritive value of intensive silvopasture systems under cut and carry systems in humid tropics of Kerala reported that among different combinations of silvopastoral systems, significantly higher dry matter yield of 31.49 t ha^{-1} was noticed for 2-tier grass tree plots (Bajra N hybrid + mulberry + calliandra) followed by Bajra Napier hybrid monoculture (30.18 tha^{-1}).

Thomas *et al.* (2021b) observed that among different agathi based fodder production systems, significantly highest dry matter yield of agathi was noticed when it was intercropped with rhodes grass under 2:2 row proportion (4.62 t ha^{-1}) and intercropping agathi with congo signal grass under 2:2 row proportion was recorded with significantly lowest dry matter yield of 2.55 t ha^{-1}.

2.1.5 Dry Matter Content

Raj *et al*. (2016) noticed that the dry matter content of fodder trees, *ie*., *Leucaena leucocephala*, *Calliandra calothyrsus* and *Morus indica* ranged from 27 to 34 per cent when compared to fodder grass (13.33%).

2.2 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY OF TOPFEEDS ON BIOMETRIC AND YIELD ATTRIBUTES OF BAJRA NAPIER HYBRID

2.2.1 Plant Height

Bajra Napier hybrid, showed an increase in height when intercropped with fodder cowpea (Jayakumar, 1997). Kumari *et al*. (2008) reported that Bajra Napier hybrid when intercropped with drumstick recorded significantly higher plant height than that of sole cropping system. Bakhashwain (2010) pointed out that the plant height of rhodes grass decreased when the proportion of alfalfa was increased in the rhodes grass-alfalfa mixture. Kimura (2018) found that the switch grass (*Panicum virgatum*) in the monoculture grew 16 cm taller than that of intercropping with poplar tree.

According to Buxton (2001), plant height of shade adapted forage crops were greater than those grown in open conditions. A study was conducted by Nadeem *et al*., (2010) on growth performance of various grass-legume mixtures and revealed that oats + vetch mixture recorded significantly higher plant height of 82.3 cm than barley + vetch mixture (70.23 cm). Thomas *et al.* (2021a) reported that plant height did not show any significant effect with respect to different grass based fodder production system in first year, however intercropping Bajra Napier hybrid with agathi in paired row recorded significantly higher plant height in second year (168 cm) and third year (181 cm).

Bhatti *et al.* (1985) observed that Napier grass planted at a spacing of 50 cm × 50 cm recorded higher plant height compared to wider spacing of 60 cm × 60 cm and 70 cm × 70 cm. Wijitphan *et al*. (2009) revealed that plant height of Napier grass was increased with plant population. Sharu (2016) revealed that palisade grass planted at a narrow spacing of 60 cm × 30 cm produced higher plant height compared to wider spacing of 60 cm × 40 cm and 60 cm × 60 cm.

2.2.2 Number of Tillers

Jayakumar (1997) revealed that Bajra Napier hybrid produced more number of tillers when intercropped with legumes in paired rows. Mariotti *et al*. (2009) reported that among different grass-legume mixtures barley-vetch mixture, produced higher number of tillers/branches. The fodder legumes *Stylosanthes* cv. seca and siratro planted in double rows had no significant advantage over single rows and did not benefit the tiller number of the fodder grasses such as Napier grass and giant panicum (Njarui *et al*., 2007). Alalade *et al*. (2013) also opined that significantly higher number of tillers was noticed in guinea grass when it was intercropped with *Stylosanthes hamata.*

According to Velayudham *et al.* (2011), adoption of wider spacing of 60 cm × 50 cm recorded more number of tillers in Bajra Naapier hybrid than that of narrow spacing at 50 cm × 50 cm. Moreover, Manjunatha *et al.* (2013) opined that perennial fodder sorghum planted with a wider row spacing of 60 cm produced more number of tillers than 45 cm or 30 cm. Adoption of wider spacing of 60 cm × 60 cm produced maximum number of tillers than narrow 60 cm × 40 cm and 60 cm × 30 cm spacing treatments in palisade grass (Sharu, 2016).

2.2.3 Leaf Stem Ratio

Jayakumar (1997) reported that intercropping BN hybrid with cowpea and lablab bean did not show any significant effect on Leaf: Stem (L: S) ratio of the grass whereas, BN hybrid sole cropping recorded highest L: S ratio. Shivprasad and Singh (2017) reported that growing fodder sorghum at 30 cm spacing recorded more leaf: stem ratio than that of 20 cm. A three year experiment was conducted by Thomas *et al*. (2021a) regarding production potential of grass based fodder production systems in the humid tropics of Kerala and the results revealed that L: S ratio was highest when BN hybrid was grown as a sole crop in first year (1.89) and third year (1.45). However Guinea grass in paired row + Agathi noticed significantly highest value in second year (3.51).

2.2.4 Tussock Diameter

Choudhary *et al*. (2012) noticed that the tussock diameter of Guinea grass was significantly superior when it was intercropped with mulberry followed by Guinea grass+ *Terminalia myriocarpa.*

2.2.5 Green Fodder Yield

According to Jayakumar (1997) Bajra Napier hybrid planted in paired row and intercropped with fodder cowpea and lablab bean recorded maximum green fodder yield compared to their sole crop. Susheela *et al*. (2015) revealed that intercropping of Subabul+ Bajra Napier hybrid + *Desmanthus* at 3:1 ratio recorded the highest green fodder yield (508.93 q ha^{-1}) followed by subabul+ Bajra Napier hybrid + stylo (501.90 q ha^{-1}) and subabul+ Bajra Napier hybrid (450.23 q ha^{-1}).

Under tropical conditions of Kerala, Bajra Napier hybrid + *Stylosanthes* mixture produced higher herbage yield than sole stand of Bajra Napier hybrid. The mixed stand of species produced 73.59 and 128.71 per cent more green and dry fodder yields, respectively over sole stand of Bajra Napier hybrid (Lakshmi *et al.*, 2002). Chauhan *et al.* (2014) observed that Bajra Napier hybrid planted in between *Leucaena leucocephala* rows produced 137.5 t ha^{-1} of green fodder yield which was at par to the yield in open (128.7 t ha^{-1}). Thomas *et al.*(2021a) noticed that among different agathi based fodder production systems, intercropping agathi with setaria in 2:2 row proportion recorded significantly highest green fodder yield of intercrop (44.14 t ha^{-1}).

The beneficial effect of Napier grass when inter cropped with subabul was recorded by Mureithi *et al*. (1995) and the study also reported an increase in yield of Napier grass when planted adjacent to subabul hedge rows than sole napier grass or Napier grass grown away from subabul. George (1996) recorded a green fodder yield of 58 t ha^{-1} for guinea grass (*Megathyrsus maximus*) grown in coconut garden.

Olanite *et al*. (2004) found that among different grass-legume combinations higher green fodder yield was obtained for *Centrosema pubescense* with *Brachiaria ruziziensis* and *Centrosema nlemfuensise*. Kumar and Naleeni (2006) observed reduction of guinea grass yield up to the tune of 48.27 and 50.10 q ha^{-1} under intercropping and mixed cropping systems, respectively.

Shahapurkar and Patil (1989) while studying the effect of improved forage species on productivity under tropical conditions of Kerala reported superiority of grass legume mixtures consisting of *Stylosanthes* and guinea or congosignal grass over monocropping system. In another study by Lakshmi *et al*. (2002) also obtained significantly better fodder yield of guinea grass and congosignal grass grown in association with *Stylosanthes hamata*.

Chhilar and Tomar (1970) reported that Bajra Napier hybrid grown with a spacing of 60 cm × 30 cm recorded higher green fodder yield than 60 cm × 50 cm spacing. Yasin *et al.* (2003) stated that planting at narrow spacing of 45 cm× 45 cm recorded higher green fodder yield of 407.9 t ha^{-1} than wider spacing of 75 cm × 75 cm in elephant grass. Sharma (2013) revealed that sewan grass (*Lasiurus scindicus* Henr.) grown at a closer spacing of 25 cm gave higher green fodder yield than a spacing of 75 cm.

2.2.6 Dry Matter Yield

Kumar and Parameswaran (1998) opined that dry matter yield of fodder crops grown in association with multipurpose trees was generally lower than that of the treeless control. Meena *et al.* (2011) reported that cow pea intercropped with *Cenchrus setigerusin* 2:1 ratio gave higher dry fodder yield of 3.35 t ha^{-1}. Varsha *et al.* (2019) noticed that Bajra Napier hybrid monoculture system produced significantly higher dry matter yield of 51.20 t ha^{-1} followed by Bajra Napier hybrid+ mulberry (48 t ha^{-1}). Ahmad *et al*. (2018) reported that intercropping of fodder grasses with either red or white clover produced significantly higher total dry fodder yield than that of sole stand of both grass and legume.

Ram and Parihar (2008) found that intercropping of Beard grass (*Chrysopogon fulvus*) with *Stylosanthes* (*Stylosanthes hamata*) in 1:1 row intercropping system produced 13.68 per cent higher dry fodder yields than that of sole stand of beard grass. Ram (2009) reported that paired row intercropping of guinea grass with *Stylosanthes hamata* gave significantly higher dry fodder yield of 5.01 t ha^{-1} in comparison to the sole stand of either grass or legume. Baba *et al.* (2011) reported that, guinea grass when intercropped with *Centrosema pubescens* in 2:2 proportions produced 7.55 per cent more dry fodder yield than that of guinea grass monoculture. Thomas *et al.* (2021b) noticed that among different agathi based fodder production systems, intercropping agathi with setaria in 2:2 row proportion noticed significantly higher dry fodder yield of intercrop (10.52 t ha^{-1}).

Mishra *et al.* (2010) reported that the total biomass production in *Cenchrus ciliaris* in terms of dry weight decreased under the tree canopies, wherein over a period of two years, *C. ciliaris* indicated 38 per cent reduction in dry matter yield under the tree canopies over the open grown grasses. Mimenza *et al*. (2013) also recorded a significant reduction in dry fodder yield of *Brachiaria brizantha* when grown underneath the tree crown of six tree species. Thomas *et al.* (2021a) reported that significantly higher dry fodder yield was noticed when BN hybrid grass (paired row) intercropped with cow pea (48.87 t ha^{-1}).

Gill and Ganwar (1990) conducted an experiment to evaluate the intensive fodder production under guava plantation and found out that pure crop of Bajra Napier hybrid gave higher dry fodder yield followed by Bajra Napier hybrid + cowpea and guinea grass + cowpea. Marchiol *et al.* (1992) reported that dry fodder yield obtained from maize-soybean intercropping was 8.9 per cent higher than pure stand of soybean and 4 per cent greater than sole crop of maize.

2.2.7 Root Weight

According to Jacob (1999), the root length of 30.56 cm and root weight of 35.36 g per plant was observed when congosignal (*Brachiaria ruziziensis*) was grown in coconut garden. Padhi and Panigrahi (2006) opined that wider spaced trees favours better root growth than narrow spaced trees. Varsha *et al.* (2019) registered that Bajra Napier hybrid+ mulberry system had recorded a root biomass of 12.07 t ha^{-1}.

2.2.8. Root Volume

George (1996) reported a root volume of 44 cm^3 and root : shoot ratio of 0.38 for guinea grass under coconut shade. Jones *et al.* (1998) observed that *Acacia nilotica* had a more negative effect on per unit root length of sorghum when grown together. Farooq *et al*. (2019) reported that the root volume of Chinese fir (*Cunninghamia lanceolata*) was significantly lower under narrow spacing than that of wider spaced trees.

2.3 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON PHYSIOLOGICAL PARAMETERS

2.3.1 Effect on Chlorophyll Content

George (1996) observed a chlorophyll content of 2.5 mg g^{-1} in guinea grass when it was grown under coconut garden. Anita (2002) reported that an increase in shade level improves the chlorophyll content of guinea grass. Oliveira *et al.*, (2013) reported that increasing chlorophyll content of crops under shaded condition becomes promising in systems of integration of pastures with trees. Chandra *et al.* (2018) conducted a study to evaluate the chlorophyll content of different *Sesbania spp.* and the result revealed that *S. sesban* produced the highest chlorophyll-a (2.190±0.142 mg per 100g) while the lowest in *S. cannabina* (1.692 ± 0.500 mg per 100 g).

2.4 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON COMPETITIVE INDICES

2.4.1 Land Equivalent Ratio (LER)

Land equivalent ratio (LER) index is used to evaluate the efficiency of intercropping using the resources of the environment compared with pure stands. If the value of LER is exceeding unity, intercropping favours the growth and the yield of species in mixture.

Ram (2009) conducted a field experiment to evaluate production potential, biological feasibility and economics of guinea grass + *Stylosanthes* intercropping systems under various fertility levels in rainfed conditions and the result revealed that intercropping of guinea grass with *S. hamata* resulted in land equivalent ratio more than one indicating intercropping advantages. Rahman *et al.* (2015) found that intercropping *Lathyrus sativus* with Napier grass noted more LER value than sole grass. Kimura *et al.* (2018) revealed that hybrid poplar tree + switchgrass intercropping system recorded 45 per cent yield advantage (LER=1.45) than that of sole cropping system.

Desale *et al*. (2002) recorded a higher LER value of 1.75 when sorghum intercropped with soybean. Moreover intercropping sorghum with cowpea recorded highest LER of 1.35 as compared to sole cropping of sorghum (Sankaranarayan *et al*., 2005). According to Gayathri (2010), in a cassava based fodder production system, alley cropping in cassava cultivar Vellayani Hraswa of six months duration with two rows of palisade grass inter planted with one row of fodder cowpea was most efficient with respect to biological productivity (cassava equivalent yield of 19.78 t ha^{-1}) and land use efficiency (LER of 1.70). Ahmed *et al.* (2013) reported that sorghum intercropped with fodder cowpea in 1:1 row proportion gave the best total LER of 2.11. Khippal *et al*. (2016) revealed that highest LER of 1.91 when sugarcane was intercropped with mustard.

2.4.3. Aggressivity

Aggressivity is an index which compares the yields between intercropping and pure cropping, and also their respective land occupancy. Mahapatra (2011) reported that aggressivity of 3.53 was noticed when sabai grass (*Eulaliopsis binata*) intercropped with black gram in 1:2 row ratio. Kumar *et al*. (2012) observed minimum aggressivity (-0.002) when maize was intercropped with field bean.

2.4.4. Relative crowding coefficient (RCC)

Ram (2009) conducted a field experiment to evaluate the production potential of guinea grass + *Stylosanthes* intercropping under different row proportions and noticed that the maximum values of the relative crowding coefficient was recorded in paired row of grass-legume intercropping, which indicated comparative yield advantage of this system over the other intercropping treatments.

Ghosh (2004) conducted a study regarding growth, yield, competition and economics of groundnut + cereal fodder intercropping systems in the semi-arid tropics of India and the result revealed that significantly greater RCC value was noticed when ground nut was intercropped with fodder maize (26.0). However the lowest value was recorded when groundnut was intercropped with pearl millet (8.7).

2.4.5. Competitive Ratio (CR)

According to Willey and Rao (1980), CR gives a better measure of competitive ability of the crops and is also advantageous as an index over RCC and aggressivity.

Tahir *et al.* (2003) reported a highest competitive ratio when wheat was intercropped with canola. In a study entitled study of grass-legume intercropping system in terms of competition indices and monetary advantage index under acid lateritic soil of India conducted by Mahapatra, (2011) reported that the significantly highest CR of 4.58 was noticed when sabai grass (*Eulaliopsis binata*) intercropped with black gram in row ratio of 3:5. Khippal *et al*. (2016) revealed that highest competitive ratio of 1.51 when sugarcane intercropped with mustard.

2.4.6 Monetary Advantage Index (MAI)

Ghosh (2004) observed that ground nut+ fodder maize intercropping system recorded significantly higher MAI (16543) and the lowest value was noticed when ground nut was intercropped with pearl millet (12656). Mahapatra, (2011) reported that significantly higher MAI value was noticed when sabai grass was intercropped with black gram under 1:2 row ratio (7254.62). Khippal *et al*. (2016) reported that among different sugarcane based intercropping systems, the highest MAI value of 75779 was obtained when sugarcane was intercropped with pea. However minimum value was obtained for sugarcane + lentil intercropping system (62382).

2.5 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON QUALITY PARAMETERS

2.5.1 Crude Protein Content

Nyambati *et al.* (2003) reported that inclusion of a legume in Napier grass based diet had shown an improvement in animal performance in terms of milk production because of their high nutrient contents. Susheela *et al*. (2015) noticed that significantly higher crude protein yield was observed when Subabul intercropped with Bajra Napier hybrid + *Desmanthus* (15.23 q ha^{-1}).

Jayakumar (1988) conducted an experiment to study the biomass productivity of guinea grass based cropping system involving C_3 (cowpea) and C_4 (maize) plants and the result revealed that intercropping guinea grass with maize and cowpea increased the protein yield compared to sole crop of Guinea grass. Somashekar *et al*. (2015) indicated that BN hybrid+ cowpea (*Kaharif*) - lucerne (*Rabi*) recorded higher crude protein yield (30 q ha^{-1}). Raj *et al*. (2016) registered that the highest crude protein yield of 4.75 t ha^{-1} was obtained from 2-tier grass-tree (Bajra Napier hybrid+ mulberry + calliandra) combination and it was 69 per cent higher than that from grass monoculture. Varsha *et al*. (2019) reported that among six different fodder production systems, significantly higher crude protein yield was noticed in mulberry monoculture (8.77 t ha^{-1}) followed by Bajra Napier hybrid + mulberry (6.30 t ha^{-1}).

Niang *et al*. (1997) reported that planting of leguminous fodder trees *viz.*, *Sesbania sesban* and *Calliandra calothyrsus* on contour lines with *Pennisetum purpureum* or *Setaria splendida* improved the herbage quality in terms of crude protein content and crude protein yield. Premi and Sood (2001) observed significant improvement in the crude protein content of herbage with the planting of siratro (*Macroptilium atropurpureum*) and setaria (*Setaria anceps*) grass in between two hedgerows of *Leucaena leucocephala* and *Robinia pseudoacacia*. Ram and Parihar (2008) reported that red beard grass (*Chrysopogon fulvus*) intercropped with *Stylosanthes* (*Stylosanthes hamata*) gave significantly higher crude protein yield (516.77 kg ha^{-1}) compared to sole cropping of grass. Chauhan *et al.* (2014) observed that subabul + Bajra Napier hybrid inter-cropping system produced 15 per cent more protein than the sole fodder crop on unit area basis.

Ram (2009) stated that intercropping of guinea grass and *Stylosanthes* in different row proportions did not significantly affect the crude protein content of *Stylosanthes*. But crude protein content of guinea grass significantly increased in paired row of intercropping as compared to its sole stand. Thomas *et al.* (2021b) found that among different agathi based fodder production systems significantly higher crude protein yield of agathi was noticed when it was intercropped with rhodes grass in 2:2 row proportion (1.25 t ha^{-1}), however significantly highest CP yield of intercrops was observed in agathi + guinea grass in 2:2 row proportion (1.28 t ha^{-1}).

Njoka-Njiru (2006) showed that Napier grass when intercropped with siratro (*Macroptilium atropurpureum* cv. Siratro) and seca (*Stylosanthes Scabra* cv. Seca) recorded more crude protein (9.64-9.96 %) than sole Napier grass (8.14 %). Kimura *et al*. (2018) observed that the crude protein content of hybrid poplar leaves was 100 mg g^{-1} when it was intercropped with switch grass than that of sole cropping of poplar tree (116 mg g^{-1}).

2.5.2 Crude Fibre Content

Rekib *et al.* (1987) observed that growing of grasses and legumes together reduced the crude fibre content of herbage mixture. Singh *et al* (1997) observed a higher crude fibre content of 33.2 per cent in brome grass when intercropped with lucerne, however the fibre content was lower when the grass was grown alone. Anita *et al*. (2014) opined that an average crude fibre content of 26.53 per cent was recorded by Bajra Napier hybrid when grown under shaded condition.

George (1996) recorded a crude fibre content of 31.9 percent for Guinea grass (*P. maximum*) grown under partially shaded coconut garden. Seresinhe and Pathirana (2000) reported a reduction in crude fiber content of guinea grass when intercropped with gliricidia.

2.6 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON SOIL NUTRIENT STATUS

Legumes benefit the grasses by the addition of nitrogen to soil through nitrogen fixation. Seresinhe *et al.* (1994) reported that inclusion of legumes in pasture mixture enhance the growth and N uptake by grass. Quick growing trees and grasses may actively withdraw soil nutrient reserves, especially during the early phase of growth and after canopy closure, they may act as self-nourishing systems (Kumar *et al*., 1998). It is well-known that plant litter acts as a temporary sink for nutrients and functions as a slow-release nutrient source thereby guaranteeing a permanent contribution of nutrients to soils (Cuevas and Medina, 1998). According to Lal and Kimble (2000), accumulation of soil organic carbon occurs primarily through the return of plant fixed carbon to the soil mainly through leaves and roots.

Alalade *et al.* (2013) reported that the pH, nitrogen, phosphorus, potassium, and organic carbon contents of the soil increased after intercropping and decreased in the control. Raj *et al*. (2016) reported that mulberry monoculture system produced more soil organic carbon content of 0.84 per cent than that of intercropping mulberry with Bajra Napier hybrid.

Susheela *et al*. (2015) opined that growing of subabul + BN hybrid + *Desmanthus virgatus,* silvipasture system resulted in higher available N (260.7 kg ha^{-1}) and K (586.8 kg ha^{-1}) over rest of the treatments while organic carbon (0.32%) was highest in subabul + Bajra Napier hybrid + *Stylosanthes* system. Manoj *et al*. (2020) stated that intercropping forage legumes with Bajra Napier hybrid improved the available N (248 to 267 kg ha^{-1}), P (22.63 to 25.67 kg ha^{-1}) and K (188.11 to 198.65 kg ha^{-1}) as compared to Bajra Napier hybrid sole cropping (219, 18.10 and 172.11 kg ha^{-1}, respectively NPK). Thomas *et al.* (2021b) reported that among different agathi based fodder production systems, significantly higher organic carbon content was noticed when agathi was intercropped with setaria in 2:2 row proportion (1.18%). However maximum soil nitrogen content was noticed when agathi intercropped with Bajra Napier hybrid in 2:1 row proportion. Significantly higher P content was found in agathi sole cropping and that of K content in agathi + rhodes grass (2:2). Montagnini and Nair, (2004) opined that including trees in pasture benefits in many ways as it improve the soil nutrient cycling, cut down soil and water runoff, mitigation of climate change *via* carbon sequestration and increased ecological connectivity.

2.7 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON CARBON SEQUESTRATION POTENTIAL

Samra *et al.* (2000) observed that in agri- silviculture growing of *Albizia procera* with different pruning regimes, the organic carbon of the soil increased by 13-16 per cent from their initial values under different pruning regimes which was 5 to 6 times higher than growing of either sole tree or sole crop. Albrecht and Kandji, (2003) revealed that agroforestry system has important role in sequestering the above ground and belowground soil carbon and hence mitigating the greenhouse effect by reducing carbon emissions.

Kirby and Potvin, (2007) reported that agroforestry system have higher carbon sequestration potential than that of field crops and tree incorporation in crop lands and pastures would result in greater net above ground as well as below ground carbon sequestration. Nair *et al.* (2009) reported that carbon sequestration potential of agroforestry system is highly variable ranging from 0.29 to 15.21 Mg ha^{-1} y^{-1} and this variation mainly due to number of factors including site characteristics, land-use types, species involved, stand age, and management practices. Yadava, (2010) estimated that eucalyptus + wheat intercropping system can sequester 14.42 t ha^{-1} of carbon in Himalayan Tarai region and 32 t ha^{-1} by poplar based agroforestry system. Dhillon *et al*. (2018) concluded that the amount of carbon sequestered by an agroforestry system largely depends on the geometry of perennial component and carbon sequestration rate is higher in closely grown trees (5 m x 4 m) than that of wide geometry.

High volume biomass production in the intercropping system will sequester large amount of C, reducing atmospheric CO_2 (Peichl *et al*., 2006). Nair *et al.* (2009) reported that the amount of C sequestered under tree and crop intercropping system ranged from 0.3 to 15.2 Mg C ha^{-1} yr^{-1} depending on tree, crop, management and environment. Another study by Fang *et al*. (2010) also found that intercropping of trees and grass will improve carbon sequestration potential of the system. Cuartas *et al*. (2014) registered that intensive silvipasture with *Leucaena leucocephala* sequesters carbon at the high end of silvopasture potential, with a potential of 8.8–26.6 t CO_2 eq ha^{-1} $year^{-1}$, alone or associated with timber trees. Raj *et al.* (2016) recorded that silvopastoral systems with higher tree densities, high yielding grass species with intensive management have higher potential to capture carbon than traditional extensive silvipasture systems with widely spaced trees with natural grasses beneath them.

Bohre *et al*. (2013) reported that 20 years old teak plantations can fix 76.6 kg carbon per tree and carbon stored in tree components were locked for a long time whereas the carbon in crops were locked for a short period only. Varsha *et al*. (2019) revealed that carbon fixation capacity of intensive Bajra Napier hybrid + mulberry silvipasture system is 11 t C ha^{-1} $year^{-1}$ and the same study also revealed that silvipasture systems with higher tree densities, high yielding grass species with intensive management under cut and carry systems have higher potential to capture carbon than traditional extensive silvopasture systems with widely spaced trees with natural grasses beneath them.

According to Lal and Kimble, (2000), accumulation of soil organic carbon occurs primarily through the return of plant fixed carbon to the soil mainly through leaves and roots. Ibrahim *et al*. (2007) reported that the carbon fixation rates of silvopasture system varied between 1.0 and 5.0 t C ha^{-1} $year^{-1}$. Meenakshi *et al*. (2010) found that carbon capturing capacity of BN hybrid was high as compared to other fodder crops like hedge lucerne, fodder cowpea and fodder maize. Adoption of intensive silvopastoral system helps to remove 26.6 t of CO_2 eq ha^{-1} $year^{-1}$ from the atmosphere equivalent to 7.24 t C as reported by Cuartas *et al*. (2014).

Thomas *et al.* (2021a) conducted an experiment entitled carbon sequestration potential of grass based fodder production systems in humid tropics of Kerala revealed that during three years of experiment growing BN hybrid in paired row with cowpea captured higher carbon of 20.69 t ha^{-1} followed by BN hybrid (paired row) + agathi (19.74 t ha^{-1}) and guinea grass (paired row) + agathi (19.33 t ha^{-1}).

2.8 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON UPTAKE OF NUTRIENTS

In a study conducted by Jayakumar (1997), intercropping Bajra Napier hybrid with lablab bean resulted in maximum uptake of N (113.10 kg ha^{-1}) and P (16.48 kg ha^{-1}). Jacob (1999) reported an uptake of 34.5 kg ha^{-1} nitrogen, 34.5 kg ha^{-1} phosphorus and 28.4 kg ha^{-1} potassium by congosignal grass (*B. ruzizensis*) grown under coconut shade. Augusto *et al*. (2002) opined that nutrient availability to plants may be greater when it was grown under trees due to higher litter inputs, higher soil moisture levels and lower soil and air temperature. Legumes based intercropping systems improve the absorption of macro and micronutrients from the soil along with nutrient use efficiency (NUE) (Crews and Peoples, 2004). Gulwa *et al*. (2017) reported that K, Ca and Mg concentrations in grasses harvested from the grass-legume mixture plots was significantly higher in comparison to those harvested from the control plots.

Wahua, (1983) reported that significantly more nitrogen and phosphorus uptake was noticed in sole cropping of maize than that of intercropping with cowpea.

2.9 EFFECT OF INTERCROPPING AND PLANTING GEOMETRY ON ECONOMICS

Place *et al.* (2009) opined that introduction of fodder trees like mulberry, *Leucaena* and calliandra in small holder farms in African countries like Uganda and Kenya improved net income of small scale dairy farmers. Thomas *et al.* (2016) concluded that fodder intercropping is economically viable in banana-based cropping system and Bajra Napier hybrid or cowpea can be cultivated profitably with banana, for maximizing land use efficiency and generating supplemental income. Susheela *et al*. (2015) noticed a Benefit: Cost ratio of 4.14, when subabul was intercropped with Bajra Napier hybrid and *desmanthes* in 3:1 ratio.

Sood and Sharma, (1996) observed that improved grass+ legume forage system registered an increase in net return by ₹ 3202 ha^{-1} over local system. Lakshmi *et al.* (2002) reported that Napier hybrid + *Stylosanthes hamata* resulted in maximum benefit cost ratio of 3.31 compared to sole planting of Bajra Napier hybrid (1.49). Ram *et al*. (2006) revealed that the average benefit cost ratio of 1.52 was registered when buffel grass intercropped with annona under hortipasture system. Ram (2009) found that guinea grass + *Stylosanthes* intercropping system registered maximum net returns of ₹ 5103 ha^{-1} under paired row system. However lowest net returns of ₹ 1684ha^{-1} was noticed in sole stand of *Stylosanthes*. Thomas *et al.* (2021a) revealed that intercropping agathi + guinea grass recorded significantly lowest cost of cultivation (₹ 240000 ha^{-1}) and highest net monetary return (₹ 355500 ha^{-1}) as well as benefit cost ratio (2.48).

A study entitled “Associative cropping pattern that enhance the animal yield” by Gopalan *et al*. (2003) revealed that there was an improvement in crude protein content when Bajra Napier hybrid intercropped with *Desmanthus virgatus.* Thomas *et al.* (2021b) reported that agathi intercropped with Bajra Napier hybrid in a proportion of 2:1 was registered with highest cost of cultivation (₹ 60600 ha^{-1}). However maximum net income (₹ 58592 ha^{-1}) and benefit cost ratio (2.07) was observed in intercropped with setaria in 2:2 row proportion.

2.10 QUALITY ASSESSMENT OF PREDOMINANT FODDER TREES AND SHRUBS OF SOUTHERN KERALA FOR FEED QUALITY

2.10.1 Proximate analysis of tree fodder

The quality of the indigenous tree leaves used as a fodder are decided based upon the proximate composition values and fiber fraction analysis (Chithra, 2018).

According to Crowder and Cheddah (1982), nutritive value of forages refers to its chemical composition, intake, digestibility and utilization of absorbed food and nature of the digested products.

2.10.1.1 Dry Matter (%)

Dry Matter (DM) is the actual amount of feed material leaving water and volatile acids and bases if present Chithra (2018) in a study revealed that dry matter content of different indigenous leguminous tree species i.e *Acacia nilotica*, *Albizia lebbeck, Dalbergio sissoo, Erythrina indica* and *Hardwickia binata* varied from 27.94 - 42.21 per cent.

Ally and Kunjikutty (2000) reported that dry matter content of banana is 25.90 per cent and that of subabul is 34.50 per cent. Gaikwad *et al*. (2017) found that the dry matter content of various fodder tree leaves and shrubs used for feeding livestock varied from 16.92 to 56.60 per cent.

2.10.1.2 Crude Protein Content (%)

Alam and Djajanigra (1994) opined that a feed with less than 10 per cent crude protein may adversely affect the rumen degradation. Gaikwad *et al.* (2017) observed that crude protein content of various fodder trees and shrubs were in the range of 1.71 to 10.44 per cent. *Moringa olifera*, *Ziziphus mauritina, Psidiun guajava*, *Sesbania sesban* and *Leucana leucocephala* recorded a protein content 7.08, 7.03, 6.74 and 6.41 per cent respectively. Chithra, (2018) observed that the highest crude protein content was observed in *Erythrina indica* tree leaves followed by *Albizia lebbeck*, *Acacia nilotica, Dalbergio sissoo*, *Hardwickia binata* respectively and crude protein content of tree leaves varied from 9.86 - 23.46 per cent.

Makkar and Becker, (1996) reported that the crude protein contents of *Moringa oleifera* leaves was 25.1 per cent. Annison and Bryden, (1998) observed the tropical tree fodders especially during dry season have low CP which is lower than the minimum CP requirements of 80 g kg^{-1} DM. Most of the tree fodders recorded medium to high concentration of crude protein and high CP value of fodder trees and shrubs make them a good protein supplement to the cattle (Abdulrazak *et al*., 2000). Ghosh and Bandyopadhyay, (2007) revealed that the crude protein content of subabul varied from 19-31 per cent. Nouman *et al*. (2013) reported that moringa has an average CP content of 15.31 per cent. However Karmakar *et al.* (2016) noticed that the crude protein content of agathi leaves as 25-30 per cent.

2.10.1.3 Crude Fibre (%)

Gaikwad *et al.* (2017) opined that the crude fiber content of fodder tree leaves and shrubs varied from 9 to 34.0 per cent and the highest value was noticed in *Ficus bengalensis* (34.0 %) followed by *Zizipus maurintina* (29.0 %) and *Syzygium cumini* (28.5 %). Chithra, (2018) observed that the highest crude fiber content among five different tree fodders *ie*., *Erythrina indica, Albizia lebbeck, Acacia nilotica, Dalbergio sissoo* and *Hardwickia binata* varied from 17.81- 28.16 per cent and significantly higher value was noticed in *Hardwickia binata.* Patric *et al*. (2020) conducted a study to evaluate the nutritive value of tree fodders in typical home garden of central Kerala and revealed that crude fiber content of various top feeds varied from 24.83- 45.9 per cent. They also noticed that among different fodder trees, moringa contained highest CF content, followed by agathi, calliandra and gliricidia.

2.10.1.4 Ether Extracts, Total Ash* and *Nitrogen Free Extract

Gaikwad *et al.* (2017) reported that higher values of ash indicated the more amount of mineral matter in the fodder tree leaves and shrubs and ash content of different fodder tree leaves and shrubs were ranged between 2.0 and 11.5 per cent. Chithra, (2018) opined that among five different tree fodders, ether extract was ranged between 3.34 - 6.17 per cent and the highest value was noticed in *Hardwickia binata* followed by *Erythrina indica, Acacia nilotica, Dalbergio sissoo,*and *Albizia lebbeck* respectively. However the total ash content of tree leaves varied from 6.86 - 9.92 per cent and the highest value was noticed in *Dalbergio sissoo* followed by *Hardwickia binata, Erythrina indica, Albizia lebbeck, Acacia nilotica,* respectively. Ally and Kunjikutty (2000) studied the chemical constituents of fourteen different tree fodders and found that banana leaves contains ether extract of 5.80 per cent and total ash content of 7.70 per cent. While subabul contains 7.40 per cent and 10.40 per cent respectively.

***2.10.1.7 Acid Detergent Fibre* (ADF) *and Neutral Detergent Fibre* (NDF)**

Neutral detergent fiber is considered to be an acceptable measure of the partially digestible cell wall contents and among different tree fodders, the amount varied from 154 to 619 g kg^{-1} DM (Nassoro, *et al*., 2014). Another study by Epafras (2019) observed that ADF content of *Morus alba* was 33 g kg^{-1} DM and that of *Glyricidia sepium* was 110g kg^{-1} DM.

Van Soest, (1994) revealed that NDF content of fodder crops ranges from 540 to 770 g kg^{-1} DM. Increasing levels of NDF may limit dry matter intake. Most of the top feed species have moderate to low contents of fibers. Mokoboki *et al.*

(2011) observed low ADF content in *Acacia hebeclada* (145 g kg^{-1} DM) and *Acacia siberiana* (165 g kg^{-1} DM) which could be associated with high digestibility. Mtui *et al*. (2009) observed low ADF content in mulberry (33 g kg^{-1} DM) and that gliricidia recorded highest ADF value of 110 g kg^{-1} DM.

Gates (1994) classified levels of acid detergent fibre in herbage for animal diet as maximum (70-75%), minimum (15-20%) and optimum (27-29%). Abdulrazak *et al.* (2000) conducted a study to determine chemical composition of selected acacia species and *Leucaena leucocephala* and the result revealed that *L. leucocephala* contains 22.4 per cent ADF and 56.3 per cent NDF. Chithra, (2018) observed that NDF values of leguminous tree leaves varied from 42.15 – 52.72 per cent and highest NDF value was observed in *Dalbergia sissoo* followed by *Hardwickia binata*, *Acacia nilotica, Erythrina indica*, *Albizia lebbeck* respectively. However ADF values of selected tree fodders varied from 28.87 - 34.21 per cent.

Chali *et al.* (2018) observed that there was 65.7 per cent ADF and 38 per cent NDF in banana leaves. A study conducted by Gaikwad *et al.* (2017) in twenty different tree fodders and shrubs revealed that the neutral detergent fiber of samples varied from 77.4 per cent (*Bambusa bambos*) to 36.0 per cent (*Moringa olifera* and *Acacia nilotica*). However the acid detergent fiber content in these fodder species were 52.9 per cent (*Bambusa bambos*), 26.9 (*Moringa olifera)* and 33.8 per cent (*Acacia nilotica*).

2.9.2 Mineral Status of Tree Fodders

Minerals are necessary for normal growth, reproduction, health and proper functioning of the animal's body (Mcdowell, 1992). Minerals protect and maintain the structural components of the body, organs and tissues and they are constituents of body fluids and tissues. Moreover minerals have catalytic functions in the cells as well as maintaining acid-base balance and osmotic control of water distribution within the body (MCdonald *et al.*, 1995).

Gaikwad *et al.* (2017) revealed that among twenty different tree fodders and shrubs, the calcium content was noticed highest in *Ficus religiosa* (4.5%) and *Albizia lebback* (4.5%) and the lowest in *Syzygium cumini* (1.0%). The highest phosphorus content was in *Ficus religiosa* (0.49%) followed by *Leucaena* *leucocephala* (0.30 %) and the least in *Bambusa bambos* (0.18%) followed by *Psidium guajava* and *Phylanthus emblica* (0.19%).

Abdulrazak *et al*. (2000) reported that *Acacia spp* had phosphorus content ranging from 0.7-1.6 g kg^{-1} DM and that of magnesium concentrations ranged from 1.3-6.6 g kg^{-1} DM. Montagnac *et al*. (2009) reported that cassava leaves are rich source of various minerals like calcium (34-708 mg kg^{-1}), phosphorus (27-211 mg kg^{-1}), potassium (2.23%) and magnesium (1.42%). Mokoboki, (2011) reported that most of the tropical leguminous fodder crops having calcium levels ranging from 8.6-10.2 g kg^{-1} DM. Sath *et al.* (2013) reported that most of the tree fodders have a phosphorus level ranging from 0.5-5 g kg^{-1} DM.

2.10.3 Micro Nutrient Status of Tree Fodders

The minimum Fe requirement for ruminants is 30-60 mg kg^{-1} DM and the Fe contents for most tropical forages and legumes range from 100-700 mg kg^{-1} DM (Khan *et al*., 2006). The levels of zinc in most of the tree fodders ranged from 10.2-34.7 mg kg^{-1} DM (Abdulrazak *et al*., 2000; Kakengi *et al*., 2007).

Rubanza (2005) reported that copper content of *Gliricidia sepium* was 4.2 m g/kg DM (*Gliricidia sepium*). Mondal *et al*. (2016) studied the micro nutrient status of different tree fodders and it was observed that banana leaves are rich in various micronutrient like Cu (10.19 ppm), Zn (14.22 ppm), Mn (47.61 ppm) and Fe (420.62 ppm). Another study conducted by Amengor *et al*. (2017) to estimate the nutritional quality of *Moringa oleifera* revealed that it is a rich source of various micro nutrients like like 0.36 ± 0.04 mg/100 g copper, 5.80 ± 0.68 mg/100 g manganese, 20.96 ± 1.37 mg/100 g iron and 6.79 ± 1.82 mg/100 g zinc.

Rubanza (2005) conducted a study on utilization of browse tree fodder supplements to ruminants fed on low quality roughages in north-western Tanzania and the result revealed that iron content of fodder trees vary from 30-60 mg kg^{-1} DM and that of manganese content from 44.6-306 mg kg^{-1} DM. Mokoboki, (2011) reported mean Zn concentration of most forages ranging from 36-47 mg kg^{-1} DM.

2.10.3. Anti-nutritional Factors in Tree Fodder

Plants produce certain chemicals which are not directly involved in the process of plant growth, however it act as deterrents to insect and fungal attack (Norton, 1990). Thus in some plants, the utility of leaves, pods and edible twigs of shrubs and trees as animal feeds is limited by the presence of anti-nutritional factors (ANFs) and its quantity vary with plant species, and stage of growth. Non-ruminants (pigs, poultry, and horses) are usually more susceptible to toxicity than ruminants. (Upreti and Shrestha, 2006).

Andrae (2008) revealed that the nitrate content of fodder at a range of 0-1000 ppm is considered as safe to cattle under all the conditions. Kumar *et al*. (2017) reported that nitrate accumulation is likely found in annual forages than in perennial fodder. The mimosine content in subabul varies from 1.02 per cent to 5.56 per cent of dry matter in leaf meal and hay and the concentration in the growing tips of the leaves and pods may reach up to 12 per cent (Lakshmi *et al*., 2020).

El-Khodery *et al*. (2008) reported that fodder with 7-16.6 per cent of oxalate may cause acute poison and death of cattle. Another study by Rahman *et al.* (2013) suggested that more than 2 per cent of soluble oxalate in fodder crops may be harmful to the ruminants.

3. MATERIALS AND METHODS

The experiment entitled "Performance and carbon sequestration potential of top feeds under varied planting geometry" was conducted at College of Agriculture, Vellayani to standardize the optimum plant population for higher green forage yield, quality and carbon sequestration potential and to assess the performance of different plant species as top feeds under sole and intercropping system. The study also envisaged to assess the quality of predominant fodder trees and shrubs of southern Kerala. The field experiment was carried out during April 2019 to April 2021. The details of the experimental materials used and methods adopted are presented in this chapter

3.1 EXPERIMENTAL SITE

The experiment was laid out at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The farm is situated at 8.5° N latitude and 76.9° E longitude and an altitude of 29 m above mean sea level.

3.1.1 Season

The experiment was conducted during the period from April 2019 to April 2021.

3.1.2 Climate

Tropical humid climate prevailed during the period of experiment. The standard week wise weather data on maximum and minimum temperature, relative humidity and rainfall received during the cropping period were collected from Class B Agromet Observatory, Department of Agricultural Meteorology, College of Agriculture, Vellayani and are furnished in Appendix 1 and graphically illustrated in Fig 1.

3.1.3. Soil

The soil of the experimental site is sandy clay loam in texture belongs to the order oxisols, Vellayani series. Before conducting the field experiment, composite soil samples were drawn from 0-15 cm depth from both open and shaded conditions and the physical and chemical properties were analysed. The data obtained is presented in Table 1.

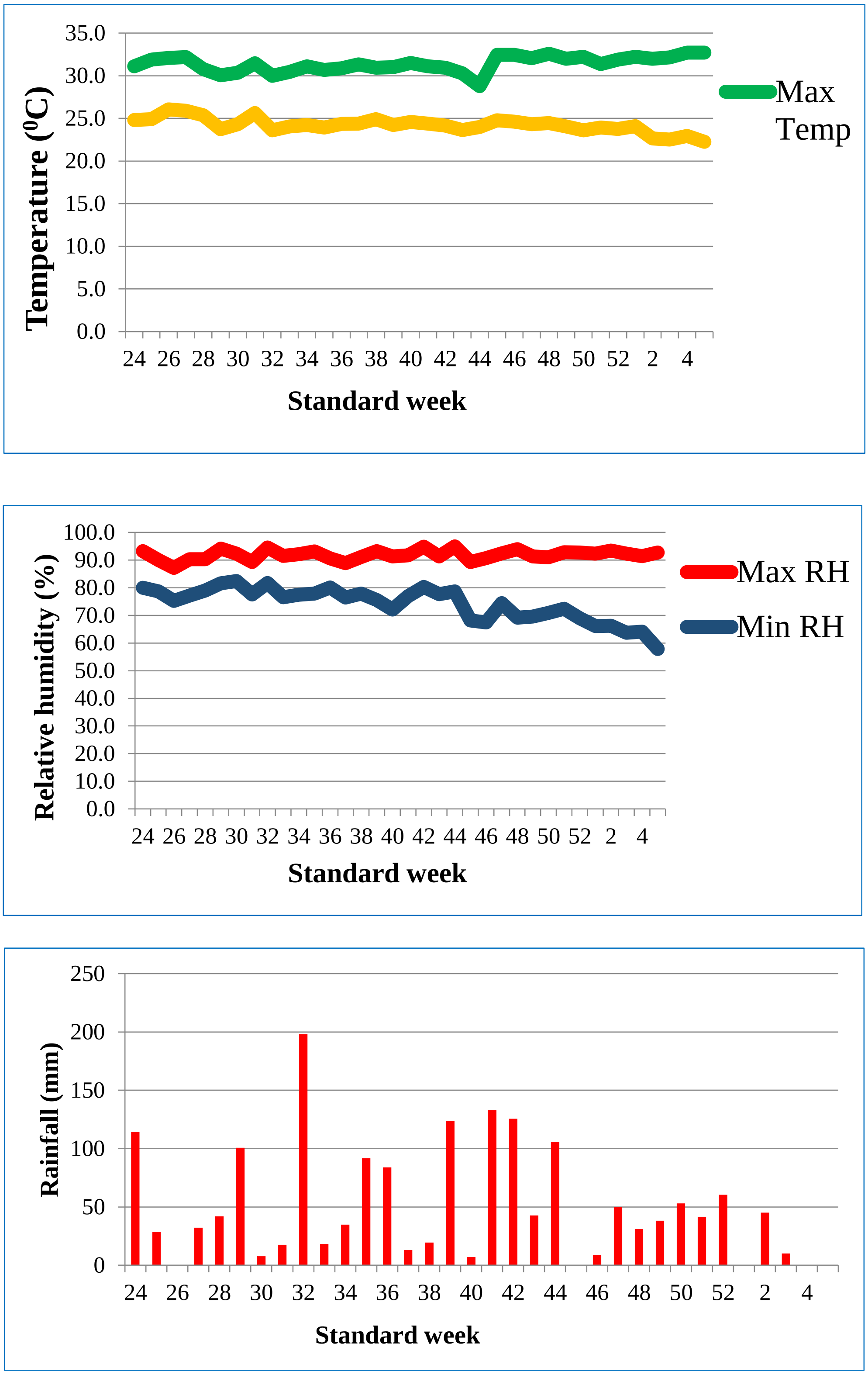
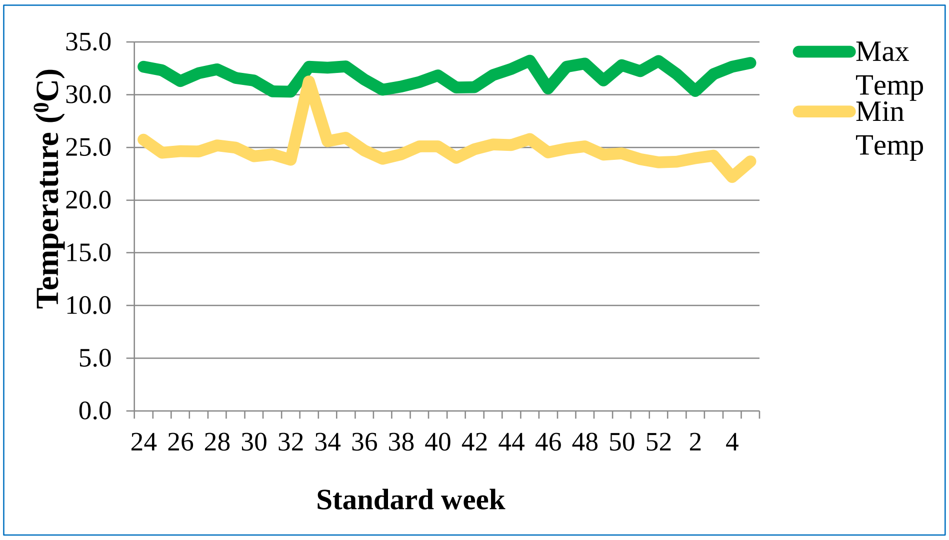
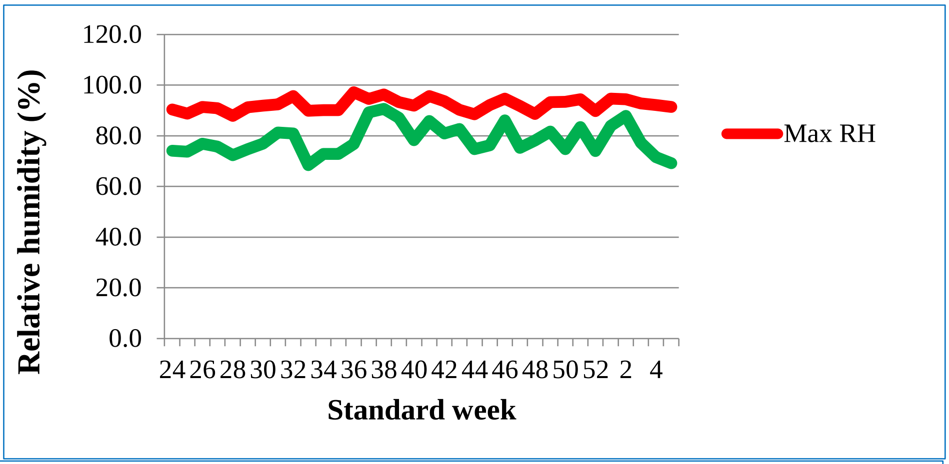


Fig. 1. Weather parameters during first year of experiment (April 2019 – April 2020)





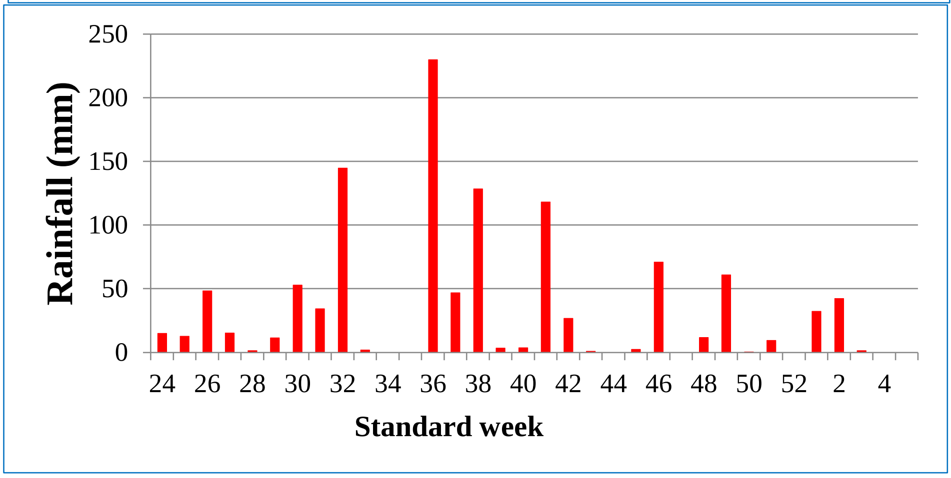


Fig. 2. Weather parameters during second year of experiment (April 2020 – April 2021)

Table 1. Soil physico - chemical properties of the experimental site

Sl. No	Parameters	Mean value	Methods adopted
	Physical properties		
1	Mechanical composition		
	Coarse sand (%)	16.70	Bouyoucos Hydrometer method (Bouyoucos ,1962)
	Fine sand (%)	31.30	
	Silt (%)	25.50	
	Clay (%)	26.50	
2	Bulk density (Mg m^{-3})	1.375	Gupta and Dakshinamoorthy, 1980
3	Water holding capacity (%)	21.50	Gupta and Dakshinamoorthy, 1980
4	Porosity (%)	32.00	Gupta and Dakshinamoorthy, 1980
	Chemical properties		
1	Soil reaction (pH)	5.37	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)
2	Electrical conductivity (dS m^{-1})	0.25	Digital conductivity meter (Jackson, 1973)
3	Organic carbon (%)	0.80 (High)	Walkley and Black rapid titration method (Jackson, 1973)
4	Available N (kg ha^{-1})	188.16 (Low)	Alkaline permanganate method (Subbiah and Asija,1956)
5	Available P_2O_5 (kg ha^{-1})	167.25 (High)	Bray colorimetric method (Jackson, 1973)
6	Available K_2O (kg ha^{-1})	102.68 (Low)	Ammonium acetate method (Jackson, 1973)

3.2 MATERIALS

3.2.1 Crop and Variety

3.2.1.1 Main crops: Agathi, Erythrina, Drumstick

Agathi (Sesbania grandiflora (L.) Pers.) is a fast-growing perennial, deciduous or evergreen nitrogen fixing legume tree that can grow up to 10-15 m height. It is highly palatable and valued fodder for ruminants. As a fast-growing, N-fixing legume, it is used for the reforestation of eroded areas and to improve soil fertility. It is often planted to make fence lines or as shade tree, windbreak and support for other crops.

Erythrina (Erythrina indica L.) is a spreading, deciduous tree legume that can reach a height of 18-25 m. It is a multipurpose tree often used in agroforestry systems and also as valuable fodder for ruminants as the foliage has a relatively high protein content that makes it an excellent feed for most livestock

Drumstick (*Moringa oleifera* Lam.) is a multipurpose tropical tree cultivated mainly for food and also used for medicinal, industrial and fodder purpose. Drumstick also known as “miracle tree” or “tree of life” is rich in nutrients, fast growing and drought tolerant. Annual green fodder yield of drumstick ranges from 100-120 t ha^{-1} in 4 to 5 cuttings, which is sufficient enough to feed 18 to 20 animals under mixed feeding system. The variety used for the study was PKM-1 developed by the Horticulture Research Station of Tamil Nadu Agricultural University (TNAU).

3.2.1.2 Intercrop: Bajra Napier hybrid

The Bajra Napier hybrid variety Suguna, released from Kerala Agricultural University was used for the study. The variety Suguna was developed by crossing Composite 9 and FD 431. It has high tillering capacity (40 tillers per plant) with long broad leaves and pale green leaf sheath with purplish segmentation and serrated leaf margin, suitable for uplands in all seasons. The average inter nodal length is 6.5cm and leaf stem ratio is 0.82. It has better quality with crude protein content of 9.4 per cent and crude fibre content of 24.0 per cent. The average yield of the variety is 280-300 t ha^{-1}. The stem cuttings of this variety required for the study was obtained from All India Coordinated Research Project on Forage Crops and Utilisation, Vellayani, Thiruvananthapuram, Kerala.

3.2.2 Manures and Fertilizers

As a source of organic manure, FYM (0.45% N, 0.17% P_2O_5 and 0.5% K_2O) was applied. The source of NPK used were urea (46 % N), rajphos (20% P_2O_5) and Muriate of potash (60% K_2O).

3.3 METHODS

3.3.1 Design and Layout

3.3.1.1 Experiment I: Performance and carbon sequestration potential of top feeds under varied planting geometry with and without intercrop

Location : Instructional farm, Vellayani

Design : Split-split plot

Treatments : 18 (2 x 3 x 3)

Replication : 3

Plot size : 6 m x 4 m

The layout of the field experiment is given in Fig.2. An overall view of the experimental field is shown in Plate 1.

Treatments

A. Main plot: Cropping system (C) -2

C_1- Sole crop (Top feeds)

C_2- Intercrop (Bajra Napier Hybrid)

B. Sub plot: Top feeds (F) -3

F_1-Agase (*Sesbania grandiflora*)

F_2-*Erythrina* (*Erythrina indica*)

F_3-Drumstick (*Drumstick oleifera*)

Note: Top feed species was harvested at a height of 75 cm

C. Sub-sub plot treatments: Planting geometry of top feeds (G) -3

G_1- 2 m x 1m

G_2- 2 m x 0.5 m

G_3- Paired system (Between pairs-2 m, within pairs-1m)

Note: Row spacing for top feed is 2 m and 3 rows of Bajra Napier Hybrid can be accommodated in this space.

3.2.1.2 Experiment II: Quality assessment of predominant fodder trees and shrubs of southern Kerala for feed quality

Treatments

T_1 : Agase (*Sesbania grandiflora*)

T_2 : *Erythrina* (*Erythrina indica*)

T_3 : Drumstick (*Moringa oleifera*)

T_4 : Coconut (*Cocos nucifera*)

T_5: Gliricidia (*Gliricidia maculata*)

T_6: Matti (*Ailanthus triphysa*)

T_7 : Subabul (*Leucaena leucocephala*)

T_8 : Cassava (*Manihot esculenta*)

T_9 : Banana (*Musa acuminata*)

T_{10} : Mango (*Mangifera indica*)

3.4 CROP HUSBANDRY PRACTICES OF EXPERIMENT 1

3.4.1 Land Preparation

The experimental area was cleared by removing the weeds and stubbles. The field was ploughed twice; clods broken and laid out into blocks and plots. The individual plots were dug and leveled.

3.4.2 Planting

The seeds of agathi, *Erythrina* and drumstick were sown in the main field and the same seeds were also sown in polybags for gap filling. The stem cuttings of Bajra Napier hybrid with three nodes were intercropped along with the main crops. The three budded cuttings were planted at a spacing of 60 cm x 60 cm in such a way that two nodes remained within the soil and one above the soil surface.

3.4.3 Gap Filling

The gap filling was done 20 DAP.

3.4.4 Manuring and Fertilizer Application

Farmyard manure (25 t ha^{-1}) was applied uniformly to all the plots at the time of final preparation of land. Chemical fertilizers like urea, Rajphos and Muriate of potash were applied to supply NPK to the crops. Bajra Napier hybrid was applied with fertilizers to supply nutrients @ 200: 50: 50 kg ha^{-1} NPK. Entire dose of phosphorus and potassium as applied as basal. Nitrogen was applied in equal split after each cut. Drumstick was applied with 100 g nitrogen and 25 g potash per plant. Half dose of nitrogen and full dose of potash was given after first harvest and remaining half dose of nitrogen was applied six months after first harvest. Moreover, agathi and *Erythrina* were fertilized with 22: 125: 21 kg ha^{-1} NPK.

3.4.5 Other Management Practices

Irrigation was provided through sprinkler method as and when required. Weeding and nitrogen application was done after each harvest.

3.4.6 Harvest

The harvest of main crops *viz*. agathi, *Erythrina* and drumstick was taken at an interval of 3 months. The first harvest of Bajra Napier hybrid was taken 75 DAP and subsequent harvests at an interval of 45 days.

3.5 QUALITY ASSESSMENT OF PREDOMINANT FODDER TREES AND SHRUBS OF SOUTHERN KERALA FOR FEED QUALITY

3.5.1 Sample Collection

Leaves from selected trees were collected from southern districts of Kerala *viz*. Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam and Alappuzha. The ten different fodder trees and shrubs included agathi (*Sesbania grandiflora)*, *Erythrina* (*Erythrina indica)*, drumstick (*Drumstick oleifera)*, coconut (*Cocos nucifera)*, *gliricidia* (*Gliricidia maculata)*, matti (*Ailanthus triphysa)*, subabul (*Leucaena leucocephala)*, cassava (*Manihot esculenta)*, banana (*Musa acuminata)* and mango (*Mangifera indica).*

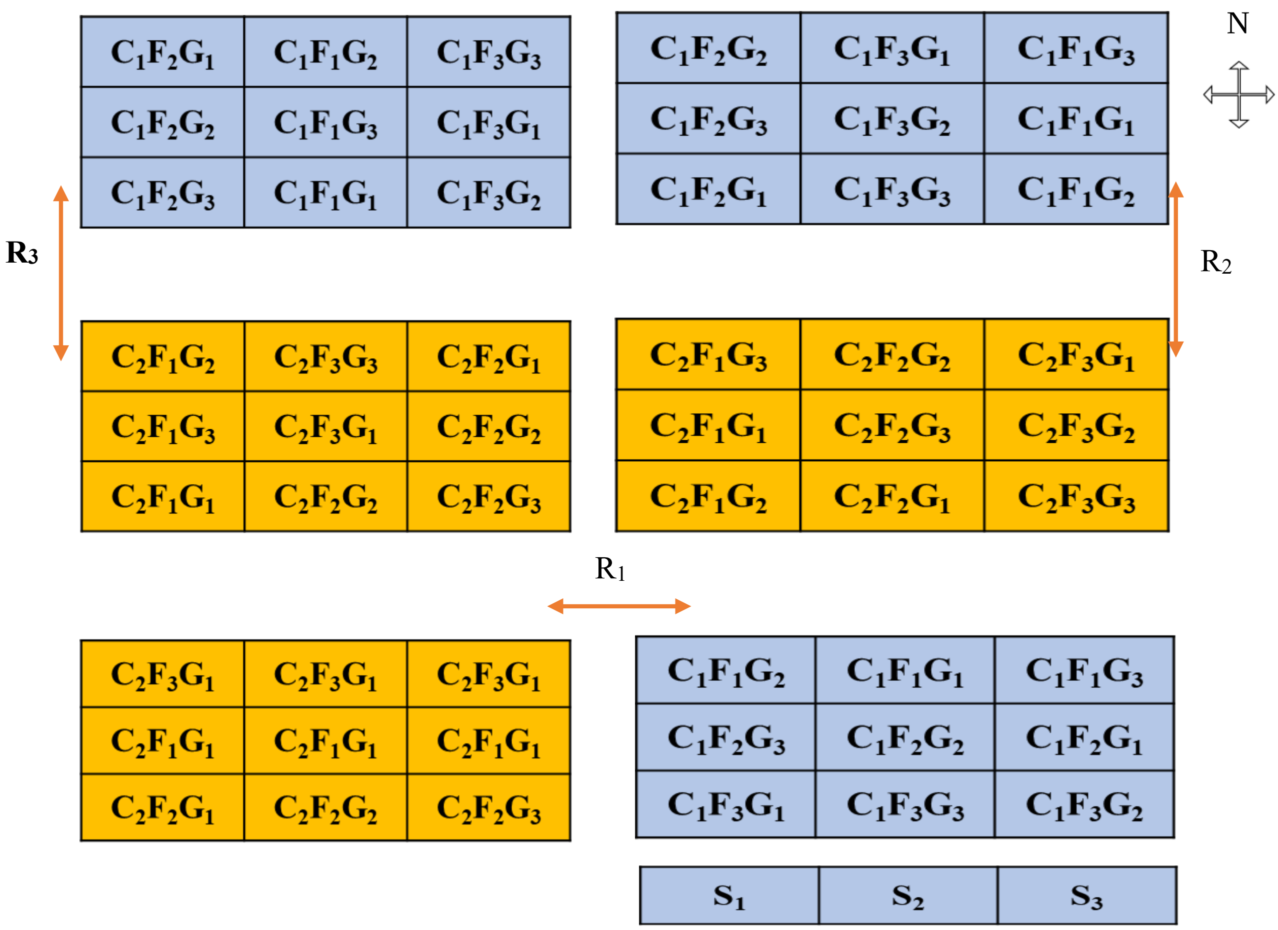


Fig. 3. Field layout of the experiment

Plate 1. General view of field experiment

Plate 2. Drumstick sole cropping system

Plate 3. ***Erythrina*+ Bajra Napier intercropping system**

Plate 4. ***Erythrina* sole cropping system**

Plate 5. Agathi+ Bajra Napier hybrid intercropping system

Plate 6. Agathi sole cropping system

Agathi

Erythrina

Drumstick

Coconut

Matti

Subabul

Cassava

Mango

Gliricidia

Banana

Plate 7. Tree fodder samples for experiment II

The green leaves were rinsed in distilled water to remove dust and stored in a refrigerator to be freeze dried as soon as possible after collection. All the foliage were cut into small pieces so as to facilitate easy handling and uniform sampling for analysis. Samples were initially sun dried followed by drying in the hot air oven at 65 ±5 ^{o}C to a constant weight. Later dried samples were ground to pass through 0.5mm sieve and stored in zip lock bags at room temperature.

3.6 OBSERVATIONS

3.6.1 Experiment- I

Five sample plants of Bajra Napier hybrid as well as three sample plants of top feeds were randomly selected from the net plot as observation plants and observations were recorded from these plants.

3.6.1.1 Biometric and yield attributes of top feed species

3.6.1.1.1 Number of Branches

The number of branches from sample plants was noted and the average calculated and recorded as number of branches per plant at each harvest.

3.6.1.1.2 Leaf: Stem Ratio

The sample plants collected at each harvest were separated into leaves and stem. The samples were sun dried and later oven dried at a temperature of 65 ±5^{o} C to a constant weight. Dry weight of stem and leaves were recorded separately for each plant and ratio was worked out. The mean leaf stem ratio was calculated

3.6.1.1.3 Green Fodder Yield

The crop was harvested at regular cutting interval, fresh weight of the plants in the net plot recorded and expressed in t ha^{-1}. Total yield for one year was also calculated and expressed in t ha^{-1}.

3.6.1.1.4 Dry Matter Yield

A weighed representative sample of green forage was obtained from each plot and dried to constant weight in an oven at 65 ±5^{o} C. Total dry matter yield was calculated from the dry weight of the sample and expressed as t ha $^{-1}$.

3.6.1.1.5 Dry Matter Content

It is the ratio of plant dry weight to that of plant fresh weight expressed in per cent.

3.6.1.1.6 Root Weight

The fresh weight of roots from each observational plant was recorded and expressed in g per plant. Later the roots were dried to constant weight in an oven at 65 ±5^{o} C and weighed to record the root dry weight in g per plant.

3.6.1.1.7 Root Volume

Root volume was measured using displacement method (Misra and Ahmed, 1989) and mean values were expressed in cm^3 per plant.

3.6.1.2 Biometric and yield attributes of Bajra Napier hybrid

3.6.1.2.1 Plant Height

The height of the sample plants were measured from the base of the plant to the tip of the longest leaf. The average was worked out at each harvest and expressed in cm.

3.6.1.2.2 Number of Tillers Hill^{-1}

From the observation plants, the number of tillers was noted and the average was calculated and expressed as number of tillers per hill at each harvest.

3.6.1.2.3 Leaf: Stem Ratio

The sample plants collected at each harvest were separated into leaves and stem and dried to a constant weight in hot air oven at 65 ±5^{o} C. Dry weight of stem and leaves were recorded separately for each plant and the ratio was worked out.

3.6.1.2.4 Green Fodder Yield

The crop was harvested at regular interval, fresh weight of the plants in the net plot was recorded and expressed in t ha^{-1}. Total yield for one year was also calculated and expressed in t ha^{-1}.

3.6.1.2.5 Dry Fodder Yield

The fresh weight of sample plants collected from each plot were recorded and subsequently the samples were sun dried and later oven dried at a temperature of 65 ±5 ^{o}C to a constant weight. The dry fodder yield was computed for each harvest as follows and expressed as t ha^{-1}.

$$\text{Dry fodder yield} = \frac{\text{Dry weight of sample plants}}{\text{Fresh weight of sample plant}} \times \text{Green fodder yield}$$

3.6.1.2.6 Tussock Diameter per Hill

Before each harvest, diameter per hill was measured from five randomly selected plants and expressed as tussock diameter per hill in cm.

3.6.1.2.7 Root Weight

The fresh weight of roots from observational plants was recorded and expressed in g per plant. Later the roots were dried to constant weight in an oven at 70 ° C and recorded as root dry weight.

3.6.1.2.8 Root Volume

Root volume was measured using displacement method (Misra and Ahmed, 1989) and mean values were expressed in cm^3 per plant.

3.6.1.3 Physiological parameters

3.6.1.3.1 Chlorophyll Content

Total chlorophyll content of top feed as well as Bajra Napier hybrid was estimated from the fully opened second leaf from the top of the sample plant and was analysed by the method suggested by Arnon (1949) and expressed in mg g^{-1} of fresh weight leaf.

$$\text{Total chlorophyll} = 8.02\ A_{663} + 20.20\ A_{645} \times \frac{V}{1000 \times W}$$

where,

A = absorbance at specific wavelengths.

V = final volume of chlorophyll extract in 80 per cent acetone.

W = fresh weight of tissue extracted in 80 per cent acetone.

3.6.1.4 Competitive indices

3.6.1.4.1 Land equivalent ratio (LER)

LER was worked out for the mixture plots using the formula suggested by Willey and Osiru (1972).

$$LER = [Yab \div (Yaa \times Zab)] + [Yba \div (Ybb \times Zba)]$$

Yaa and Ybb are the sole crop yield and Yab and Yba are the individual crop yields in intercropping system. Zab and Zba are the proportion of land area occupied in intercropping when compared to sole crop for species a and b respectively.

3.6.1.4.2 Area time equivalent ratio (ATER)

ATER was worked out by using the formula put forward by Hiebsch (1978).

$$ATER = [(RYa \times ta) + (RYb \times tb)(RYc \times tc] \div T$$

RY = relative yield of species a (agathi), b (*Erythrina*) and c (drumstick)

t = duration (days) for species a, b and c

T = duration (days) of the intercropping system

3.6.1.4.3 Aggressivity

The method proposed by Mc Gilchrist (1965) was adopted to assess how much relative yield increase in species A is greater than that of B in an intercropping system.

$$Aab = Yab / Yaa\ Zab - Yba / Ybb\ Zba$$

where,

Yaa = pure stand yield of species a

Ybb = pure stand yield of species b

Yab= mixture yield of species ‘a’ in combination with ‘b’

Yba = mixture yield of species ‘b’ in combination with ‘a’

Zab= sown proportion of species ‘a’ in mixture with ‘b’

Zba = sown proportion of species ‘b’ in mixture with ‘a’

3.6.1.4.4 Relative crowding coefficient (RCC)

RCC was worked out using the formula proposed by de Wit (1960).

$$Kab = Yab \div [(Yaa - Yab)Zab]$$

$$Kba = Yba \div [(Ybb - Yba)Zba]$$

Kab and Kba = product of coefficient of species a and b respectively

3.6.1.4.5 Competitive ratio (CR)

Competitive ratio (CR) is proposed by Willey and Rao (1980) as a measure of intercrop competition, to indicate the number of times by which one component crop is more competitive than the other.

$$Crab = (L\ E\ R_a / LER_b)\ X\ Z_{ba}/Z_{ab}$$

3.4.1.4.6 Monetary advantage Index (MAI)

The economic feasibility of intercropping over sole cropping was calculated using the monetary advantage index (MAI). MAI is an important index in determining economic viability of intercropping. It was calculated as suggested by Willey (1979)

For a dual-crop mixture, the minimum expected productivity

$$MAI = \frac{Value\ of\ combined\ intercrops\ X\ (LER - 1)}{LER}$$

3.6.1.5. Quality characters

3.6.1.5.1 Crude Protein Content

The crude protein content was calculated by multiplying the nitrogen content of the plant by the factor 6.25 (Simpson *et al.,* 1965).

3.6.1.5.2 Crude Fibre Content

The crude fibre content was detrmined by AOAC method (AOAC, 1975).

3.6.1.6 Uptake Studies

Samples were collected at harvest, chopped, sundried and oven dried (65 ±5^o C) to a constant weight. Samples were ground to pass through a 0.5 mm mesh in a Willey Mill and required quantity of samples were digested and used for nutrient analysis**.**

3.6.1.6.1 Uptake of Nitrogen

The nitrogen content in plant was estimated by modified microkjeldhal method (Jackson, 1973). The uptake of N by the fodder crop was calculated as the product of the content of the nutrient in plants and the dry weight of plants and expressed as kg ha^{-1}.

3.6.1.6.2 Uptake of Phosphorus

The phosphorus content in the plant was estimated colorimetrically by Vanado - molybdate yellow colour method using spectrophotometer (Jackson, 1973). The phosphorus uptake was calculated by multiplying the phosphorus content with dry weight of plants. The values were expressed in kg ha^{-1}.

3.6.1.6.3 Uptake of Potassium

The potassium content in the plant samples was determined by the flame photometric method (Jackson, 1973). The uptake of potassium was calculated as product of potassium content and dry weight of plants and expressed in kg ha^{-1}.

3.6.1.7 Carbon sequestration potential of the system

The oven dried samples of top feeds and Bajra Napier hybrid were ground thoroughly to pass through 2 mm sieve and used for analyzing the carbon concentrations, by igniting in muffle furnace at 550° C for 6 h (Gaur, 1975). Carbon content in the each samples were multiplied with the corresponding component dry biomass (Nair *et al*., 2010) and summed up to calculate the overall plant carbon stocks of various systems and expressed on hectare basis.

3.6.1.8 Soil Analysis

The soil samples were collected before and after from individual plots of the experimental area. The composite samples drawn from the individual plots were air dried in shade, powdered, sieved through 2 mm sieve and analyzed for available nitrogen, available phosphorus, available potassium and organic carbon content. The available nitrogen content was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956), the available phosphorus content was estimated by Bray's colorimetric method (Jackson, 1973), available potassium by neutral normal ammonium acetate method (Jackson, 1973) and organic carbon content by Walkley and Black rapid titration method (Jackson, 1973).

3.6.2 Experiment-II

3.6.2.1. Proximate analysis of tree fodders

Proximate composition such as crude protein (CP), ether extract (EE), crude fibre (CF) and total ash (TA) were analysed by standard methods (AOAC, 2012). The fibre fractions viz. neutral detergent fiber, (NDF) and acid detergent fiber (ADF) were determined by the method suggested by Van Soest *et al*. (1991). Dry matter content was calculated by drying the sample at 60^{o} C in hot air oven till the constant weight. The phosphorus content of the samples were analysed colorimetrically by vanado-molybdate yellow colour method using spectrophotometer and potassium by flame photometric method. The magnesium and calcium content in plant samples were estimated using atomic absorption spectrophotometry (Jackson, 1973).

3.6.2.1.1 Dry matter

Dry matter content was calculated by drying the sample at 65 $\pm 5^{o}$ C in hot air oven till the constant weight.

3.6.2.1.2 Crude protein

Crude protein content of the samples were calculated by multiplying the nitrogen content of plant samples by the factor 6.25 (Simpson *et al*., 1965) and expressed in percentage.

3.6.2.1.3 Crude fibre

Crude fibre content of the samples were determined by A. O. A. C. method (AOAC, 1975) and expressed in per cent.

3.6.2.1.4 Ether extract

Ether extract of the plant samples which represent the crude fat content of the samples were estimated by extracting crude fat by using organic solvent petroleum benzene (AOAC, 1975) and expressed in percentage.

3.6.2.1.5 Total ash

Total ash content of the plant samples was determined by igniting a known quantity of sample at 600^{0} C for three hours (AOAC, 1975)

3.6.2.1.6 Nitrogen free extract

Nitrogen free extract was determined by subtracting percentage crude protein, crude fiber, ether extract and total ash from 100.

3.6.2.1.7 Acid detergent fibre and neutral detergent fibre

Acid detergent fibre and neutral detergent fibre was determined by Van Soest *et al*. (1991).

3.6.2.1.8 Phosphorus

The phosphorus content in the plant was estimated colorimetrically by vanado-molybdate yellow colour method using spectrophotometer (Jackson, 1973).

3.6.2.1.9 Potassium (K)

The potassium content in the plant samples was determined by the flame photometric method (Jackson, 1973).

3.6.2.1.10 Calcium and magnesium

The calcium and magnesium content in plant samples were estimated using Atomic absorption spectrophotometry (Jackson, 1973).

3.6.2.1.11 Ca: Mg ratio

The calcium and magnesium content in plant samples were estimated using atomic absorption spectrophotometry (Jackson, 1973) and the ratio were computed.

3.6.2.1.12 K: Ca ratio

The potassium content in the plant samples was analysed by the flame photometric method and that of calcium content by atomic absorption spectrophotometry (Jackson, 1973) and the ratio were computed.

3.6.2.1.13 Iron and zinc

The content of micro nutrients viz., iron and zinc, in plant samples were estimated by Atomic absorption spectrophotometry (Jackson, 1973).

3.7 ECONOMIC ANALYSIS

Economics was worked out for the experiment based on the prevailing output and input market price of the fodder crop.

3.7.1 Net Income

The net income was calculated by subtracting cost of cultivation from gross income and expressed in ₹ ha^{-1}.

Net income (₹ ha^{-1}) = Gross income (₹ ha^{-1}) - Cost of cultivation (₹ ha^{-1}).

3.7.2 B: C ratio

B: C ratio was worked out as the ratio of gross income to cost of cultivation.

$$\text{B: C ratio} = \frac{\text{Gross income (₹)}}{\text{Cost of cultivation ha}^{-1}\text{ (₹)}}$$

3.8 STATISTICAL ANALYSIS

The data on various parameters were statistically analysed using analysis of variance technique (ANOVA) for split split plot experiment and the significance was tested by F test. If the effects were found to be significant, CD (P=0.05) values were calculated at five per cent probability level.

4. RESULTS

The present experiment entitled "Performance and carbon sequestration potential of top feeds under varied planting geometry" was conducted at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during April 2019 to April 2021 to standardize the optimum plant population for higher green forage yield, quality and carbon sequestration potential and to assess the performance for different plant species as top feeds under sole and intercropping system. The study also envisaged to assess the quality of predominant fodder trees and shrubs of southern Kerala. The experimental data collected were analysed statistically and the results are presented in this chapter.

4.1 EXPERIMENT 1: PERFORMANCE AND CARBON SEQUESTRATION POTENTIAL OF TOP FEEDS UNDER VARIED PLANTING GEOMETRY

4.1.1 Growth and yield attributes of top feeds during first year

The observations on growth and yield attributes of top feeds like number of branches, leaf stem ratio, green fodder yield, dry fodder yield and dry matter content were recorded and the results are presented below.

4.1.1.1 Number of branches

The result of the effect of cropping system, top feeds and spacing of top feeds on number of branches of top feeds in four harvests during first year are presented in Tables 2a, 2b and 2c.

The data on mean number of branches of top feeds over all the harvests revealed that mean number of branches did not vary significantly with different cropping system and planting geometry of top feeds. However, considering different top feeds in sub plot, agathi recorded significantly higher mean number of branches (12.23). Regarding the interaction between cropping system and top feeds, C_1F_1 recorded higher mean number of branches (12.37) and it was on par with C_2F_1. Results of the interaction between cropping system and planting geometry revealed that the treatment combination C_1G_1 recorded significantly higher mean number of branches of 12.37 during the first year. Considering the interaction between top feeds and planting geometry, mean branch number was the highest for F_1G_1 (12.95) and it was on par with F_1G_2. The mean number of branches significantly varied with respect to the interaction between cropping system, top feeds and planting geometry with higher mean value in $C_1F_1G_1$ (14.43).

The data on number of branches of top feeds over four harvests during first year revealed that the number of branches of top feeds was significantly higher under sole cropping than intercropping in second and third harvest (9.97 and 8.08), whereas number of branches did not vary significantly in first and fourth harvest. Among top feeds, agathi recorded significantly highest number of branches in all the four harvests (12.26, 14.3, 11.72 and 10.62 respectively), whereas the lowest number was observed in drumstick. The number of branches did not vary significantly with respect to planting geometry of top feeds in any of the harvest.

The interaction effect of cropping system with top feeds was found to be significant in first and third harvest. C_1F_1 recorded the highest number of branches in first harvest (12.65) and it was on par with C_2F_1, whereas in the third harvest, C_2F_1 recorded the highest value (11.99) and it was on par with C_1F_1.The interaction effect of cropping system with spacing (CG) and top feeds with spacing (FG) were found to be non-significant in all the four harvests.

The number of branches of top feeds were not varied significantly with respect to interaction of cropping system, top feeds and planting geometry in all harvests except the second and higher number of branches was observed in $C_1F_1G_1$ (18.51) and it was on par with $C_1F_1G_2$ (15.80).

Table 2a. Effect of cropping system, top feeds and planting geometry on number of branches of top feeds during first year

Treatments	Number of branches				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
Cropping system (C)					
C_1: Sole crop (Top feeds)	7.89	9.97	8.08	6.79	8.18
C_2 : Intercrop (Bajra Napier Hybrid)	7.55	8.66	7.95	6.88	7.76
SEm (±)	0.32	0.06	0.02	0.05	0.08
CD (P=0.05)	NS	0.367	0.127	NS	NS
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	12.26	14.30	11.72	10.62	12.23
F_2: *Erythrina* (*Erythrina indica*)	6.57	7.92	6.61	5.69	6.70
F_3: Drumstick (*Moringa oleifera*)	4.32	5.72	5.71	4.19	4.99
SEm (±)	0.32	0.50	0.18	0.30	0.15
CD (P=0.05)	1.056	1.638	0.585	0.982	0.480
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	7.79	9.47	8.36	6.76	8.10
G_2: 2 m x 0.5 m	7.08	9.67	7.75	6.60	7.78
G_3: Paired system	8.28	8.80	7.93	7.14	8.04
SEm (±)	0.47	0.52	0.39	0.35	0.19
CD (P=0.05)	NS	NS	NS	NS	NS

NS: Not significant

Table 2b. Effect of C x F, C x G and F x G interactions on number of branches of top feeds during first year.

Treatments	Number of branches				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
C_1F_1	12.65	15.30	11.45	10.09	12.37
C_1F_2	7.61	9.40	7.21	6.22	7.61
C_1F_3	3.40	5.20	5.57	4.06	4.56
C_2F_1	11.88	13.30	11.99	11.16	12.08
C_2F_2	5.53	6.44	6.01	5.16	5.79
C_2F_3	5.24	6.24	5.85	4.33	5.42
SEm (±)	0.46	0.71	0.25	0.43	0.21
CD (P=0.05)	1.494	NS	0.827	NS	0.679
C_1G_1	8.32	10.94	9.05	6.81	12.37
C_1G_2	6.73	10.17	7.73	6.28	7.61
C_1G_3	8.61	8.79	7.45	7.27	8.03
C_2G_1	7.27	7.99	7.67	6.71	7.41
C_2G_2	7.43	9.17	7.77	6.93	7.83
C_2G_3	7.95	8.81	8.42	7.02	8.05
SEm (±)	0.66	0.74	0.55	0.49	0.27
CD (P=0.05)	NS	NS	NS	NS	0.781
F_1G_1	12.42	15.15	13.36	10.87	12.95
F_1G_2	12.17	14.83	10.87	10.52	12.10
F_1G_3	12.20	12.92	10.93	10.48	11.63
F_2G_1	6.54	7.58	6.50	5.45	6.51
F_2G_2	5.42	8.32	6.13	5.17	6.26
F_2G_3	7.76	7.86	7.20	6.46	7.32
F_3G_1	4.43	5.67	5.22	3.96	4.82
F_3G_2	3.66	5.88	6.25	4.12	4.98
F_3G_3	4.88	5.61	5.67	4.49	5.16
SEm (±)	0.81	0.91	0.68	0.60	0.33
CD (P=0.05)	NS	NS	NS	NS	0.957

NS: Not significant

Table 2c. Interaction effect of cropping system, top feeds and planting geometry on number of branches of top feeds during first year

Treatments	**Number of branches**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
$C_1F_1G_1$	14.07	18.51	14.49	10.66	14.43
$C_1F_1G_2$	12.08	15.80	10.77	10.11	12.19
$C_1F_1G_3$	11.80	11.59	9.08	9.48	10.49
$C_1F_2G_1$	7.78	9.21	7.49	6.15	7.66
$C_1F_2G_2$	5.65	8.85	6.30	5.00	6.45
$C_1F_2G_3$	9.40	10.13	7.86	7.52	8.73
$C_1F_3G_1$	3.10	5.10	5.18	3.63	4.26
$C_1F_3G_2$	2.46	5.87	6.12	3.74	4.55
$C_1F_3G_3$	4.62	4.65	5.41	4.81	4.87
$C_2F_1G_1$	10.77	11.79	12.23	11.08	11.47
$C_2F_1G_2$	12.26	13.85	10.97	10.93	12.00
$C_2F_1G_3$	12.59	14.26	12.78	11.47	12.78
$C_2F_2G_1$	5.29	5.94	5.51	4.74	5.37
$C_2F_2G_2$	5.19	7.78	5.96	5.34	6.07
$C_2F_2G_3$	6.12	5.59	6.55	5.41	5.92
$C_2F_3G_1$	5.75	6.24	5.26	4.30	5.39
$C_2F_3G_2$	4.85	5.89	6.38	4.51	5.41
$C_2F_3G_3$	5.13	6.58	5.92	4.17	5.45
SEm (±)	1.15	1.28	0.96	0.85	0.46
CD (P=0.05)	NS	3.747	NS	NS	1.353

NS: Not significant

4.1.1.2 Leaf stem ratio

The data on effect of cropping system, top feeds and spacing on leaf stem ratio of top feeds over four cuts during first year are furnished in Tables 3a, 3b and 3c.

Data of mean leaf stem ratio over all the harvests revealed that the cropping system did not vary significantly in the first year. Among different top feeds, the mean leaf stem ratio was found significantly higher in agathi (0.76) over rest of the top feeds. Among three planting geometry of top feeds, treatment G_1 (2 m x 1 m) recorded significantly higher mean leaf stem ratio of 0.74 during first year.

The interaction between cropping system and top feeds did not show any significant effect on mean leaf stem ratio, however the interaction between cropping system and planting geometry had significant influence on mean leaf stem ratio and significantly higher mean leaf stem ratio was noticed in C_1G_1 (0.80). Moreover, significant interaction between top feeds and spacing was also observed with respect to mean leaf stem ratio and significantly higher value was noticed in F_1G_1 (0.83). The result also shown that no significant interaction between cropping system, top feeds and planting geometry was noticed with respect to mean leaf stem ratio of top feeds over first year.

The data on leaf stem ratio over four different harvests during first year revealed that the leaf stem ratio was not varied significantly with respect to cropping system in all harvests except in the third harvest. However growing top feeds as sole crops recorded significantly higher leaf stem ratio in third harvest (0.72). In the case of subplot factor, leaf stem ratio differed significantly in all harvests except first harvest. At the second harvest, *Erythrina* recorded significantly higher leaf stem ratio (0.81), whereas agathi observed to be superior with respect to leaf stem ratio in third and fourth harvests (0.79 and 0.81 respectively). In the case of sub-sub plot factor, significant difference was observed in all harvests except first. Growing top feeds at a spacing of 2 m x 1 m (G_1) was observed significantly superior with respect to the leaf stem ratio in second, third and fourth harvest (0.83, 0.76 and 0.77 respectively).

Interaction effect of cropping system with top feeds did not differ significantly at first, third and fourth harvest. However, treatment combination C_1F_2 recorded significantly higher value at second harvest (0.94). The same trend was also observed in the interaction of cropping system and spacing in which no significant effect was observed in all harvests except the second harvest (0.93). Moreover, significant interaction between top feeds and spacing was observed in leaf stem ratio of first and second harvest during first year. At first harvest, F_1G_1 recorded higher leaf stem ratio of 0.74 and it was on par with F_1G_3, F_2G_2, F_2G_3 and F_3G_3. However at second harvest, F_2G_1 recorded the highest value of 0.96 and it was on par with F_1G_1, F_1G_2, and F_2G_3.

Significant interaction between cropping system, top feeds and planting geometry was noticed only in second and fourth harvests. $C_1F_2G_3$ registered significantly higher value (1.23) in second harvest whereas $C_2F_1G_2$ recorded the highest value in fourth harvest (0.94) and it was on par with $C_2F_1G_1$, $C_1F_1G_1$, $C_1F_1G_3$, and $C_1F_2G_1$.

Table 3a. Effect of cropping system, top feeds and planting geometry on leaf stem ratio of top feeds during first year

Treatments	Leaf stem ratio of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Mean
Cropping system (C)					
C_1: Sole crop (Top feeds)	0.66	0.83	0.72	0.70	0.73
C_2 : Intercrop (Bajra Napier Hybrid)	0.58	0.68	0.64	0.67	0.64
SEm (±)	0.03	0.03	0.01	0.03	0.02
CD (P=0.05)	NS	NS	0.069	NS	NS
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	0.63	0.79	0.79	0.81	0.76
F_2: *Erythrina* (*Erythrina indica*)	0.65	0.81	0.63	0.63	0.68
F_3: Drumstick (*Moringa oleifera*)	0.58	0.66	0.61	0.62	0.62
SEm (±)	0.04	0.02	0.03	0.02	0.01
CD (P=0.05)	NS	0.077	0.093	0.073	0.043
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	0.61	0.83	0.76	0.77	0.74
G_2: 2 m x 0.5 m	0.65	0.66	0.66	0.62	0.65
G_3: Paired system	0.60	0.77	0.62	0.67	0.67
SEm (±)	0.03	0.04	0.03	0.02	0.01
CD (P=0.05)	NS	0.104	0.096	0.066	0.039

Table 3b. Effect of C x F, C x G and F x G interactions on leaf stem ratio of top feeds during first year

Treatments	Leaf stem ratio of top feeds				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
C_1F_1	0.72	0.79	0.84	0.78	0.78
C_1F_2	0.67	0.94	0.66	0.65	0.73
C_1F_3	0.60	0.75	0.67	0.66	0.67
C_2F_1	0.54	0.79	0.75	0.83	0.73
C_2F_2	0.63	0.68	0.60	0.62	0.63
C_2F_3	0.56	0.56	0.56	0.58	0.56
SEm (±)	0.05	0.03	0.04	0.03	0.02
CD (P=0.05)	NS	0.109	NS	NS	NS
C_1G_1	0.65	0.91	0.83	0.81	0.80
C_1G_2	0.66	0.64	0.67	0.59	0.64
C_1G_3	0.68	0.93	0.67	0.69	0.74
C_2G_1	0.58	0.74	0.69	0.72	0.68
C_2G_2	0.64	0.69	0.64	0.66	0.66
C_2G_3	0.51	0.61	0.58	0.64	0.59
SEm (±)	0.04	0.05	0.05	0.03	0.02
CD (P=0.05)	NS	0.147	NS	NS	0.055
F_1G_1	0.74	0.85	0.89	0.86	0.83
F_1G_2	0.54	0.79	0.84	0.78	0.74
F_1G_3	0.61	0.73	0.65	0.77	0.69
F_2G_1	0.55	0.96	0.73	0.74	0.75
F_2G_2	0.71	0.60	0.56	0.52	0.60
F_2G_3	0.69	0.89	0.61	0.64	0.70
F_3G_1	0.55	0.67	0.66	0.70	0.64
F_3G_2	0.69	0.60	0.56	0.58	0.61
F_3G_3	0.50	0.70	0.62	0.59	0.60
SEm (±)	0.05	0.06	0.06	0.04	0.02
CD (P=0.05)	0.132	0.181	NS	NS	0.067

NS: Not Significant

Table 3c. Interaction effect of cropping system, top feeds and planting geometry on leaf stem ratio of top feeds during first year

Treatments	Leaf stem ratio of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Mean
$C_1F_1G_1$	0.84	0.85	0.94	0.92	0.89
$C_1F_1G_2$	0.53	0.73	0.87	0.63	0.69
$C_1F_1G_3$	0.80	0.80	0.71	0.80	0.78
$C_1F_2G_1$	0.54	0.96	0.86	0.81	0.80
$C_1F_2G_2$	0.77	0.64	0.52	0.52	0.61
$C_1F_2G_3$	0.70	1.23	0.59	0.60	0.78
$C_1F_3G_1$	0.56	0.93	0.69	0.71	0.72
$C_1F_3G_2$	0.68	0.55	0.62	0.63	0.62
$C_1F_3G_3$	0.54	0.77	0.70	0.66	0.67
$C_2F_1G_1$	0.64	0.86	0.83	0.80	0.78
$C_2F_1G_2$	0.55	0.85	0.82	0.94	0.79
$C_2F_1G_3$	0.42	0.66	0.60	0.74	0.61
$C_2F_2G_1$	0.56	0.95	0.59	0.67	0.69
$C_2F_2G_2$	0.66	0.56	0.60	0.51	0.58
$C_2F_2G_3$	0.67	0.54	0.62	0.67	0.62
$C_2F_3G_1$	0.56	0.95	0.63	0.69	0.57
$C_2F_3G_2$	0.66	0.56	0.51	0.52	0.59
$C_2F_3G_3$	0.67	0.54	0.53	0.52	0.53
SEm (±)	0.06	0.09	0.08	0.06	0.03
CD (P=0.05)	NS	0.255	NS	0.161	NS

NS: Not significant

4.1.1.3. Green fodder yield

The data on effect of cropping system, top feeds and spacing on the green fodder yield of top feeds during first year are presented in Tables 4a, 4b and 4c.

The data on total green fodder yield of top feeds over first year revealed that cropping system had significant influence on total green fodder yield and significantly higher value was noticed in intercropping system(18.3t ha^{-1} yr^{-1}) than sole cropping (12.84t ha^{-1} yr^{-1}). Among three different top feeds, agathi recorded significantly higher total green fodder yield of 21.61t ha^{-1} yr^{-1}, whereas *Erythrina* recorded the lowest value of 9.65 t ha^{-1} yr^{-1}. Regarding the sub-sub plot factor, the highest total green fodder yield of 16.27 t ha^{-1} yr^{-1} was noticed in G_3 and the value was comparable to G_2. Regarding the interaction between cropping system and top feeds, the total green fodder yield was significantly higher for C_2F_1 (25.87 t ha^{-1} yr^{-1}).With respect to interaction between cropping system and planting geometry, higher total GFY was noticed in C_2G_2 (19.19 t ha^{-1} yr^{-1}) and it was on par with C_2G_3 (18.97 t ha^{-1} yr^{-1}). Considering the interaction between top feeds and planting geometry, F_1G_2 registered significantly higher total GFY of 23.83 t ha^{-1} yr^{-1}. Significant interaction between cropping system, top feed and spacing was noticed with respect to total GFY during first year and significantly higher total GFY was noticed in $C_2F_1G_2$ (30.53 t ha^{-1} yr^{-1}).

The result on green fodder yield of top feeds over four harvests during first year showed that green fodder yield of top feeds significantly varied with cropping systems in first, second, third and fourth harvests and intercropping recorded significantly higher values. Among the three different top feeds, agathi recorded significantly higher green fodder yield (4.54, 5.76, 6.83 4.48 t ha^{-1}respectively) and *Erythrina* registered significantly lower green fodder yield in all the four harvests. Among three planting geometry, G_3 recorded the highest green fodder yield in first, second and fourth harvests (3.32 t ha^{-1}, 4.35 t ha^{-1} and 3.39 t ha^{-1}respectively) and it was on par with G_2 (3.19 t ha^{-1},4.21 t ha^{-1} and 3.28 t ha^{-1}respectively). However in the third harvest, G_2 recorded higher green fodder yield (5.23 t ha^{-1}) and remained on par with G_3 (3.28 t ha^{-1}).

Among different treatment combinations in sub plot, C_2F_1 was significantly superior with respect to the green fodder yield in all the four harvests and the highest green fodder yield was recorded in third harvest (8.08 t ha^{-1}) followed by second (6.99 t ha^{-1}) and fourth harvest (5.42 t ha^{-1}).The result also revealed that there was significant interaction between cropping system and spacing in all harvests except the first and fourth harvest. C_2G_2 was superior with respect to the green fodder yield in second and third harvest (5.13 t ha^{-1} and 6.31 t ha^{-1} respectively).

Significant interaction between top feed and spacing was observed in green fodder yield of top feeds and it was also observed that F_1G_2 recorded higher yield of 4.86 t ha^{-1}, 6.30 t ha^{-1}, 7.72 t ha^{-1}, and 4.97 t ha^{-1}respectively in first, second, third and fourth harvest and the values were on par with F_1G_3 in first, second and fourth harvest.

Significant interaction between cropping system, top feed and spacing was observed in green fodder yield of top feeds in all harvests and significantly higher value was noticed in $C_2F_1G_2$ in first (6.06 t ha^{-1}), second (8.04 t ha^{-1}), third (10.00 t ha^{-1}) and fourth (6.43 t ha^{-1}) harvest.

Significant interaction between cropping system and top feed was recorded in all the four harvests. The treatment combination C_2F_1 recorded significantly higher dry fodder yield in first (1.38 t ha^{-1}), second (1.61 t ha^{-1}), third (2.16 t ha^{-1}) and fourth (1.29 t ha^{-1}) harvests. The interaction effect of cropping system and spacing on dry fodder yield was significant for C_2G_2 in second harvest (1.31 t ha^{-1}) and for C_2G_3 (1.68 t ha^{-1}) in third harvest. However the dry fodder yield yield was not significant in first and fourth harvests. Significant interaction between top feed and spacing was observed in dry fodder yield of top feeds and it was also observed that F_1G_2 recorded higher yield of 1.25 t ha^{-1}, 1.56 t ha^{-1} and 1.21 t ha^{-1}respectively in first, second and fourth harvests and the values were on par with F_1G_3 in first and fourth harvests. However F_1G_3 recorded higher dry fodder yield in third harvest (1.94 t ha^{-1}) and the value was comparable with F_1G_2.

Significant interaction between cropping system, top feed and spacing was observed in dry fodder yield of top feeds in all harvests and significantly higher value was noticed in $C_2F_1G_2$ in first (1.57 t ha^{-1}), second (2.00 t ha^{-1}), third (2.49 t ha^{-1}) and fourth (1.54 t ha^{-1}) harvest.

Table 4a. Effect of cropping system, top feeds and planting geometry on green fodder yield of top feeds during first year, t ha^{-1}

Treatments	Green fodder yield of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
Cropping system (C)					
C_1: Sole crop (Top feeds)	2.65	3.33	4.19	2.66	12.84
C_2 :Intercrop(Bajra Napier Hybrid)	3.73	4.88	5.91	3.77	18.30
SEm (±)	0.040	0.150	0.025	0.032	0.105
CD (P=0.05)	0.248	0.926	0.157	0.198	0.651
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	4.54	5.76	6.83	4.48	21.61
F_2: *Erythrina* (*Erythrina indica*)	1.91	2.54	3.23	1.95	9.65
F_3: Drumstick (*Moringa oleifera*)	3.11	4.01	5.10	3.22	15.44
SEm (±)	0.07	0.09	0.06	0.08	0.14
CD (P=0.05)	0.230	0.303	0.189	0.260	0.468
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	3.06	3.76	4.73	2.97	14.53
G_2: 2 m x 0.5 m	3.19	4.21	5.23	3.28	15.91
G_3: Paired system	3.32	4.35	5.20	3.39	16.27
SEm (±)	0.07	0.07	0.04	0.11	0.15
CD (P=0.05)	0.199	0.213	0.112	0.306	0.427

Table 4b. Effect of C x F, C x G and F x G interactions on green fodder yield of top feeds during first year, t ha^{-1}

Treatments	Green fodder yield of top feeds				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Total**
C_1F_1	3.72	4.54	5.57	3.53	17.36
C_1F_2	2.01	2.67	3.46	2.13	10.29
C_1F_3	2.22	2.79	3.55	2.31	10.87
C_2F_1	5.37	6.99	8.08	5.42	25.87
C_2F_2	1.81	2.41	3.00	1.77	9.01
C_2F_3	4.00	5.24	6.64	4.13	20.02
SEm (±)	0.22	0.13	0.08	0.11	0.20
CD (P=0.05)	0.067	0.428	0.267	0.368	0.662
C_1G_1	2.58	3.19	4.03	2.51	12.31
C_1G_2	2.58	3.29	4.14	2.61	12.62
C_1G_3	2.79	3.52	4.41	2.86	13.58
C_2G_1	3.54	4.33	5.43	3.43	16.74
C_2G_2	3.79	5.13	6.31	3.96	19.19
C_2G_3	3.85	4.74	5.99	3.93	18.97
SEm (±)	0.10	0.10	0.05	0.15	0.21
CD (P=0.05)	NS	0.301	0.158	NS	0.603
F_1G_1	4.17	4.88	5.99	3.78	18.88
F_1G_2	4.86	6.30	7.72	4.97	23.83
F_1G_3	4.60	6.11	6.77	4.68	22.17
F_2G_1	1.91	2.48	3.09	1.97	9.46
F_2G_2	1.85	2.51	3.31	1.88	9.56
F_2G_3	1.97	2.64	3.29	2.00	9.92
F_3G_1	3.08	3.92	5.10	3.17	15.28
F_3G_2	2.85	3.82	4.65	3.00	14.32
F_3G_3	3.39	4.30	5.54	3.50	16.73
SEm (±)	0.12	0.13	0.07	0.18	0.25
CD (P=0.05)	0.345	0.369	0.194	0.530	0.739

Table 4c. Interaction effect of cropping system, top feeds and planting geometry on green fodder yield of top feeds during first year, t ha^{-1}

Treatments	Green fodder yield of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
$C_1F_1G_1$	3.70	4.17	5.27	3.20	16.33
$C_1F_1G_2$	3.66	4.55	5.44	3.50	17.13
$C_1F_1G_3$	3.79	4.89	6.01	3.90	18.60
$C_1F_2G_1$	1.89	2.53	3.19	2.07	9.70
$C_1F_2G_2$	2.04	2.69	3.66	2.20	10.60
$C_1F_2G_3$	2.10	2.79	3.52	2.13	10.57
$C_1F_3G_1$	2.14	2.86	3.62	2.27	10.90
$C_1F_3G_2$	2.03	2.63	3.33	2.13	10.13
$C_1F_3G_3$	2.48	2.87	3.69	2.53	11.57
$C_2F_1G_1$	4.65	5.58	6.71	4.37	21.33
$C_2F_1G_2$	6.06	8.04	10.00	6.43	30.53
$C_2F_1G_3$	5.40	7.35	7.52	4.47	25.73
$C_2F_2G_1$	1.93	2.43	2.99	1.87	9.23
$C_2F_2G_2$	1.66	2.33	2.95	1.57	8.53
$C_2F_2G_3$	1.83	2.49	3.05	1.87	9.27
$C_2F_3G_1$	4.03	4.98	6.58	4.07	19.67
$C_2F_3G_2$	3.66	5.02	5.97	3.87	18.50
$C_2F_3G_3$	4.31	5.72	7.38	4.47	21.90
SEm (±)	0.17	0.18	0.09	0.26	0.36
CD (P=0.05)	0.488	0.522	0.274	0.749	1.045

4.1.1.4. Dry fodder yield

The data on the effect of cropping system, top feeds and spacing on the dry fodder yield of top feeds during first year are furnished in Tables 5a, 5b and 5c.

The data on total dry fodder yield of top feeds over four different harvests during first year revealed that growing top feeds along with Bajra Napier hybrid (C_2) registered significantly higher total dry fodder yield of 4.57 t ha^{-1} yr^{-1}. However C_1 recorded significantly lower total dry fodder yield of 3.25 t ha^{-1} yr^{-1}. Considering three different top feeds that were grown in subplot, agathi recorded significantly higher total dry fodder yield of 5.40 t ha^{-1} yr^{-1}. At the same time *Erythrina* had the lowest total dry fodder yield (2.44 t ha^{-1} yr^{-1}). Regarding the planting geometry of top feeds, paired system of planting (G_3) was observed to be significantly superior with respect to total dry fodder yield of 4.10 t ha^{-1} yr^{-1}. The interaction between cropping system and top feeds with respect to total dry fodder yield was found to vary significantly and higher value was noticed in C_2F_1 (6.44 t ha^{-1} yr^{-1}). However considering the interaction between cropping system and planting geometry, the highest total dry fodder yield was noticed in C_2G_2 (4.80 t ha^{-1} yr^{-1}) and it was on par with C_2G_3. Significant interaction between top feeds and planting geometry was noticed with respect to total dry fodder yield and higher value was noticed in F_1G_2 (5.95 t ha^{-1} yr^{-1}). Considering the interaction between cropping systems, top feeds and planting geometry, total dry fodder yield was significantly superior in $C_2F_1G_2$ (7.63 t ha^{-1} yr^{-1})

The data on dry fodder yield of top feeds at each harvest during first year revealed that growing top feeds in intercropping system recorded significantly higher dry fodder yield of top feeds in first (0.95 t ha^{-1}), second (1.19 t ha^{-1}), third (1.52 t ha^{-1}) and fourth (0.92 t ha^{-1}) harvest. Among different sub plot factors, agathi recorded significantly higher dry fodder yield at all harvests. (1.14 t ha^{-1}, 1.37 t ha^{-1}, 1.78 t ha^{-1} and 1.09 t ha^{-1} respectively). Among three planting geometry, G_3 registered higher dry fodder yield in first and fourth harvests (0.83 t ha^{-1} and 1.39 t ha^{-1}). At first harvest, it was on par with G_2 (0.81 t ha^{-1}) .However in second harvest, G_2 was observed to be higher in dry fodder yield (1.07 t ha^{-1}) and it was on par with G_3 (1.04 t ha^{-1}). However total dry fodder yield was higher in G_3 (4.10 t ha^{-1} yr^{-1}).

Table 5a. Effect of cropping system, top feeds and planting geometry on dry fodder yield of top feeds during first year, t ha^{-1}

Treatments	**Dry fodder yield of top feeds**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Total**
Cropping system (C)					
C_1: Sole crop (Top feeds)	0.66	0.86	1.06	0.68	3.25
C_2 :Intercrop(Bajra Napier Hybrid)	0.95	1.19	1.52	0.92	4.57
SEm (±)	0.01	0.03	0.01	0.01	0.03
CD (P=0.05)	0.057	0.194	0.068	0.039	0.205
Top feeds (F)					
F_1: Agathi(*Sesbania grandiflora*)	1.14	1.38	1.78	1.09	5.40
F_2: *Erythrina* (*Erythrina indica*)	0.48	0.66	0.80	0.51	2.44
F_3: Drumstick (*Moringa oleifera*)	0.79	1.02	1.29	0.79	3.89
SEm (±)	0.02	0.02	0.01	0.02	0.04
CD (P=0.05)	0.054	0.067	0.035	0.074	0.126
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	0.76	0.96	1.18	0.76	3.65
G_2: 2 m x 0.5 m	0.81	1.07	1.30	0.80	3.98
G_3: Paired system	0.84	1.04	1.39	0.83	4.10
SEm (±)	0.02	0.02	0.01	0.03	0.03
CD (P=0.05)	0.057	0.061	0.028	NS	0.098

Table 5b. Effect of C x F, C x G and F x G interactions on dry fodder yield of top feeds during first year, t ha^{-1}

Treatments	Dry fodder yield of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
C_1F_1	0.91	1.14	1.40	0.90	4.35
C_1F_2	0.52	0.68	0.87	0.53	2.59
C_1F_3	0.55	0.76	0.91	0.59	2.79
C_2F_1	1.38	1.61	2.16	1.29	6.44
C_2F_2	0.44	0.64	0.74	0.48	2.29
C_2F_3	1.04	1.32	1.67	0.98	4.99
SEm (±)	0.023	0.029	0.015	0.032	0.055
CD (P=0.05)	0.076	0.094	0.049	0.105	0.178
C_1G_1	0.64	0.84	1.03	0.63	3.14
C_1G_2	0.65	0.84	1.04	0.65	3.17
C_1G_3	0.69	0.89	1.11	0.74	3.43
C_2G_1	0.89	1.08	1.32	0.89	4.16
C_2G_2	0.98	1.31	1.57	0.95	4.80
C_2G_3	0.98	1.19	1.68	0.91	4.76
SEm (±)	0.027	0.029	0.014	0.035	0.047
CD (P=0.05)	NS	0.086	0.040	NS	0.138
F_1G_1	1.01	1.22	1.48	0.96	4.68
F_1G_2	1.25	1.56	1.92	1.21	5.95
F_1G_3	1.17	1.34	1.94	1.12	5.57
F_2G_1	0.49	0.64	0.71	0.55	2.37
F_2G_2	0.46	0.66	0.83	0.46	2.40
F_2G_3	0.49	0.68	0.87	0.52	2.55
F_3G_1	0.79	1.02	1.34	0.78	3.90
F_3G_2	0.74	0.99	1.16	0.74	3.60
F_3G_3	0.86	1.04	1.38	0.85	4.17
SEm (±)	0.03	0.04	0.02	0.04	0.06
CD (P=0.05)	0.098	0.105	0.049	0.127	0.169

NS: Not significant

Table 5c. Interaction effect of cropping system, top feeds and planting geometry on dry fodder yield of top feeds during first year, t ha^{-1}

Treatments	**Dry fodder yield of top feeds**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Total**
$C_1F_1G_1$	0.87	1.07	1.36	0.80	4.10
$C_1F_1G_2$	0.93	1.13	1.35	0.87	4.27
$C_1F_1G_3$	0.93	1.23	1.50	1.03	4.68
$C_1F_2G_1$	0.51	0.65	0.77	0.52	2.44
$C_1F_2G_2$	0.50	0.68	0.93	0.53	2.64
$C_1F_2G_3$	0.54	0.69	0.91	0.56	2.70
$C_1F_3G_1$	0.55	0.80	0.97	0.59	2.87
$C_1F_3G_2$	0.50	0.70	0.83	0.56	2.59
$C_1F_3G_3$	0.61	0.76	0.92	0.63	2.92
$C_2F_1G_1$	1.15	1.37	1.60	1.13	5.25
$C_2F_1G_2$	1.57	2.00	2.49	1.54	7.63
$C_2F_1G_3$	1.41	1.46	2.38	1.20	6.45
$C_2F_2G_1$	0.48	0.62	0.65	0.57	2.30
$C_2F_2G_2$	0.41	0.64	0.74	0.40	2.16
$C_2F_2G_3$	0.43	0.67	0.82	0.48	2.40
$C_2F_3G_1$	1.03	1.24	1.70	0.97	4.93
$C_2F_3G_2$	0.97	1.28	1.48	0.92	4.62
$C_2F_3G_3$	1.10	1.45	1.83	1.06	5.42
SEm (±)	0.05	0.05	0.02	0.06	0.08
CD (P=0.05)	0.139	0.149	0.069	0.179	0.239

4.1.1.5 Dry matter content

The data on effect of cropping system, top feeds and spacing on dry matter content of top feeds during first year are furnished in Tables 6a, 6b and 6c.

The results revealed that the mean dry matter content of top feeds in did not vary significantly with respect to different cropping systems. In the case of subplot factor, mean dry matter content was higher for *Erythrina* (25.42 %) and it was on par with drumstick. However mean dry matter content did not vary significantly with planting geometry of top feeds. Considering the interaction between cropping system and top feeds, the mean dry matter content was observed to be higher for C_1F_3 (25.74 %) and it was comparable with C_2F_2. At the same time the interaction between cropping system and planting geometry did not vary significantly with respect to mean dry matter of top feeds during first year. Considering the interaction between top feeds and spacing, F_2G_3 had noticed the highest mean dry matter content of 25.65 per cent and it was on par with F_2G_1, F_3G_1 and F_3G_2. Regarding the interaction between cropping system, top feeds and planting geometry, the mean dry matter content did not vary significantly over first year.

Regarding individual harvest data, significant variation was noticed only in second and fourth harvest. Growing top feeds as sole crops recorded significantly higher dry matter content in second (25.89 %) and fourth harvests (25.41 %). In the case of subplot factor, dry matter content differed significantly in second and third harvest. At second harvest, higher dry matter content was observed in drumstick (26.15 %) and the value was comparable with *Erythrina* (25.95 %). Significantly higher dry matter content of 26 per cent was recorded by agathi in third harvest. In the case of sub-sub plot factor, significant difference with respect to dry matter content was observed in all harvests except first. Growing top feeds at a spacing of 2 m x 0.5 m (G_2) was observed to be superior with respect to the dry matter content in second harvest (25.79 %) and it was on par with G_1 (25.70 %). However G_3 recorded significantly higher dry matter content in third harvest (26.49 %) and G_1 in the fourth harvest (26.15 %).

Regarding the interaction effect of cropping system with top feeds in each harvest of first year, at first harvest, C_2F_3 and C_2F_1 recorded higher dry matter content (25.91 %) and it was on par with C_1F_1 (24.56 %), C_1F_2 (25.58 %), C_1F_3 (24.92 %) and. At second harvest, C_1F_3 recorded higher dry matter content of 27.15 per cent and it was on par with C_2F_2 (26.58 %). However C_2F_1 recorded significantly higher value in third harvest (26.82 %).The highest dry matter content of 27.41 per cent was noticed at fourth harvest and it was on par with C_1F_3. Significant interaction between cropping system and spacing was observed in dry matter content of top feeds in all four harvests except first harvest. Higher dry matter content of 26.48 per cent was noticed in C_1G_1 and it was on par with C_2G_2 (25.94 %) in second harvest. Whereas C_2G_3 was superior in third harvest (27.82 %). In fourth harvest, the highest dry matter content was observed in C_2G_1 (26.95 %) and it was on par with C_1G_1 (25.35 %) and C_1G_3 (25.84 %). Considering the interaction between top feeds and spacing on mean dry matter content of top feeds in first year revealed that the variation in dry matter content of top feeds was not-significant in first and fourth harvests. F_2G_2 recorded significantly the highest dry matter content of 26.49 per cent in second harvest and F_1G_3 registeredsignificantly highest value (28.31 %) in third harvest.

Significant interaction among cropping system, top feeds and planting geometry was noticed in dry matter content of second and third harvest. Regarding each harvests, $C_1F_3G_1$ registered higher value (27.94 %) in second harvest and it was on par with $C_2F_2G_2$ (27.58 %), whereas $C_2F_1G_3$ recorded significantly higher value in third harvest (31.77 %). However the interaction remained non-significant in first and fourth harvest.

Table 6a. Effect of cropping system, top feeds and planting geometry on dry matter content of top feeds during first year, per cent

Treatments	**Dry matter content of top feeds**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
Cropping system (C)					
C_1: Sole crop (Top feeds)	25.02	25.89	25.29	25.41	25.37
C_2 :Intercrop (Bajra Napier Hybrid)	25.36	24.94	25.50	25.07	25.15
SEm (±)	0.27	0.08	0.04	0.05	0.06
CD (P=0.05)	NS	0.509	NS	0.285	NS
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	25.23	24.15	26.00	24.67	25.02
F_2: *Erythrina* (*Erythrina indica*)	24.92	25.95	24.85	26.23	25.42
F_3:Drumstick (*Moringa oleifera*)	25.42	26.15	25.34	24.81	25.33
SEm (±)	0.32	0.16	0.09	0.44	0.08
CD (P=0.05)	NS	0.528	0.280	NS	0.258
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	25.09	25.70	24.73	26.15	25.35
G_2: 2 m x 0.5 m	25.39	25.79	24.95	24.67	25.14
G_3: Paired system	25.10	24.75	26.50	24.88	25.28
SEm (±)	0.32	0.15	0.08	0.41	0.09
CD (P=0.05)	NS	0.444	0.228	1.194	NS

NS: Not significant

Table 6b. Effect of C x F, C x G and F x G interactions dry matter content of top feeds during first year, per cent

Treatments	Dry matter content of top feeds				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
C_1F_1	24.56	25.22	25.17	25.36	25.08
C_1F_2	25.58	25.31	25.18	25.05	25.28
C_1F_3	24.92	27.15	25.51	25.81	25.74
C_2F_1	25.91	23.08	26.82	23.97	24.95
C_2F_2	24.27	26.58	24.51	27.41	25.57
C_2F_3	25.91	25.15	25.17	23.81	24.91
SEm (±)	0.45	0.23	0.12	0.62	0.11
CD (P=0.05)	1.465	0.746	0.396	2.005	0.365
C_1G_1	25.25	26.48	25.62	25.35	25.58
C_1G_2	24.87	25.65	25.07	25.02	25.15
C_1G_3	24.94	25.55	25.17	25.84	25.38
C_2G_1	24.92	24.92	23.85	26.95	25.12
C_2G_2	25.91	25.94	24.84	24.32	25.12
C_2G_3	25.25	23.95	27.82	23.92	25.19
SEm (±)	0.46	0.22	0.11	0.58	0.13
CD (P=0.05)	NS	0.628	0.322	1.689	NS
F_1G_1	24.11	25.16	24.84	25.34	24.89
F_1G_2	25.99	24.79	24.84	24.38	24.99
F_1G_3	25.60	22.50	28.31	24.28	25.17
F_2G_1	25.58	25.59	23.03	28.15	25.50
F_2G_2	24.60	26.50	25.18	24.62	25.12
F_2G_3	24.60	25.75	26.33	25.93	25.65
F_3G_1	25.58	26.35	26.33	24.97	25.66
F_3G_2	25.58	26.09	24.84	25.01	25.30
F_3G_3	25.09	26.01	24.84	24.44	25.03
SEm (±)	0.56	0.26	0.14	0.71	0.15
CD (P=0.05)	NS	0.769	0.394	NS	0.447

NS: Not significant

Table 6c. Interaction effect of cropping system, top feeds and planting geometry on dry matter content of top feeds during first year, per cent

Treatments	**Dry matter content of top feeds**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
$C_1F_1G_1$	23.61	25.75	25.84	24.88	25.02
$C_1F_1G_2$	25.42	24.76	24.84	24.74	24.94
$C_1F_1G_3$	24.64	25.16	24.84	26.46	25.27
$C_1F_2G_1$	26.56	25.75	24.19	25.02	25.38
$C_1F_2G_2$	24.60	25.42	25.51	24.10	24.91
$C_1F_2G_3$	25.58	24.76	25.84	26.04	25.55
$C_1F_3G_1$	25.58	27.94	26.83	26.15	26.33
$C_1F_3G_2$	24.60	26.76	24.84	26.23	25.60
$C_1F_3G_3$	24.60	26.74	24.84	25.03	25.30
$C_2F_1G_1$	24.60	24.58	23.85	25.80	24.75
$C_2F_1G_2$	26.56	24.82	24.84	24.02	25.05
$C_2F_1G_3$	26.56	19.83	31.78	22.10	25.07
$C_2F_2G_1$	24.60	25.44	21.86	31.28	25.63
$C_2F_2G_2$	24.60	27.58	24.84	25.13	25.33
$C_2F_2G_3$	23.61	26.74	26.83	25.82	25.75
$C_2F_3G_1$	25.58	24.76	25.84	23.78	24.99
$C_2F_3G_2$	26.56	25.41	24.84	23.80	24.99
$C_2F_3G_3$	25.58	25.29	24.84	23.85	24.76
SEm (±)	0.79	0.37	0.19	1.00	0.22
CD (P=0.05)	NS	1.087	0.558	NS	NS

NS: Not significant

4.1.2 Growth and yield attributes of top feeds during second year

The observations on growth and yield attributes of top feeds like number of branches, leaf stem ratio, green fodder yield, dry fodder yield, dry matter content during second year and root weight and root volume after two years were recorded and the results are presented below.

4.1.2.1 Number of branches

The results of the effect of cropping system, top feeds and spacing of top feeds on number of branches of top feeds in four harvests during second year are presented in Tables 7a, 7b and 7c.

The results showed that intercropping had significant effect on the mean number of branches of top feeds during the second year. Among three different top feeds, the mean branch number was significantly superior for agathi (14.70). Regarding planting geometry, average number of branches was the highest for G_3 (10.09) and it was on par with G_1. Significant influence of interaction between cropping system and top feeds on mean number of branches was observed during second year and C_2F_1 had higher value (16.08). At the same time the interaction between cropping system and planting geometry did not vary significantly with respect to average number of branches of top feeds. With respect to the interaction between top feeds and planting geometry, superior value was noticed in F_1G_3 (14.88) and it was comparable with F_1G_1 and F_1G_2. The data on interaction effect of cropping system, top feeds and planting geometry on mean number of branches of top feeds revealed that the treatment combination $C_2F_1G_3$ was superior (16.74) and it was on par with $C_2F_1G_2$ (16.41).

The data on number of branches of top feeds with respect to cropping system varied significantly in second (11.58) and third (10.98) harvests, whereas no significant effect was noticed in first and fourth harvests. Among top feeds, the same trend was noticed as in first year. Number of branches varied significantly with different top feeds in all harvests except the first harvest. Agathi recorded significantly higher number of branches in second, third and fourth harvests (16.99, 16.01 and 11.47 respectively) whereas drumstick recorded the lowest number (6.87, 6.12 and 5.92 respectively). Regarding planting geometry, numbers of branches were not significantly different in first and fourth harvest, whereas in second harvests, G_1 recorded higher number of branches (11.08) and it was on par with G_2 (10.79). However paired system of planting (G_3) recorded significantly higher value in third harvest (11.04).

The interaction effect of cropping system with top feeds did not vary significantly in first and fourth harvests, whereas the treatment combination C_2F_1 recorded significantly higher number of branches in second (17.42) and third harvests (18.72).The interaction effect of cropping system with spacing (CG) varied significantly in all harvests except third harvest. At first harvest, C_1G_3 recorded higher number of branches (10.95) and it was on par with C_1G_1 (10.89). C_2G_1 recorded significantly more number of branches (12.87) in third harvest. However C_1G_1 topped in the fourth harvest (8.79) and it was on par with C_1G_2 (8.06), C_2G_1 (8.07), and C_2G_3 (8.40). Interaction between top feeds and spacing with respect to mean number of branches of top feeds revealed that F_1G_3 recorded the highest mean number of branches over second year (14.88) and it was on par with F_1G_1 and F_1G_2. The result also revealed that at first and second harvests, F_1G_1 was superior (14.39 and 17.84 respectively) and it was on par with F_1G_2 (14.32) and F_1G_3 (13.09) in first harvest and on par with F_1G_2 (16.84) in second harvest. Treatment combination of agathi with paired system of planting (F_1G_3) recorded significantly more number of branches in third harvest (17.38) and it was on par with F_1G_2 (17.01).However, higher value of 12.43 was recorded by F_1G_1 in fourth harvest and it was on par with F_1G_3 (11.62).

The data on interaction effect of cropping system, top feeds and planting geometry on number of branches of top feeds revealed that treatment combination $C_2F_1G_2$ had more number of branches in first (16.01), second (18.99) and third (21.53) harvests, whereas $C_1F_1G_1$ was superior in fourth harvest (13.71).The superior value of $C_2F_1G_2$ in first and third harvests were on par with $C_2F_1G_3$ (14.00 and 19.19 respectively).

Table 7a: Effect of cropping system, top feeds and planting geometry on number of branches of top feeds during second year

Treatments	Number of branches				
	Harvest I	Harvest II	Harvest III	Harvest IV	Mean
Cropping system (C)					
C_1: Sole crop (Top feeds)	10.22	9.52	8.83	8.14	9.18
C_2 : Intercrop (Bajra Napier Hybrid)	9.36	11.58	10.98	7.92	10.19
SEm (±)	0.22	0.24	0.09	0.13	0.13
CD (P=0.05)	NS	1.451	0.534	NS	0.770
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	13.93	16.00	16.01	11.47	14.70
F_2: *Erythrina* (*Erythrina indica*)	9.01	8.78	7.57	6.71	8.02
F_3: Drumstick (*Moringa oleifera*)	6.421	6.868	6.124	5.918	6.33
SEm (±)	0.45	0.11	0.45	0.23	0.14
CD (P=0.05)	NS	0.361	1.451	0.750	0.448
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	9.97	11.08	8.81	8.43	9.57
G_2: 2 m x 0.5 m	9.20	10.79	9.86	7.68	9.38
G_3: Paired system	10.19	9.77	11.04	7.99	10.09
SEm (±)	0.31	0.21	0.40	0.21	0.19
CD (P=0.05)	NS	0.616	1.156	NS	0.555

NS : Not significant

Table 7b. Effect of C x F, C x G and F x G interactions on number of branches of top feeds during second year

Treatments	**Number of branches**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
C_1F_1	13.57	14.58	13.30	11.83	13.32
C_1F_2	10.26	6.55	7.41	6.90	7.78
C_1F_3	6.82	7.42	5.77	5.70	6.43
C_2F_1	14.30	17.42	18.72	11.11	16.08
C_2F_2	7.76	11.00	7.74	6.52	8.26
C_2F_3	6.02	6.32	6.48	6.13	6.24
SEm (±)	0.63	0.16	0.09	0.33	0.20
CD (P=0.05)	NS	0.511	0.534	NS	0.634
C_1G_1	10.89	9.29	7.68	8.79	9.16
C_1G_2	8.81	9.90	8.41	8.06	8.80
C_1G_3	10.95	9.35	10.38	7.58	9.57
C_2G_1	9.06	12.87	9.93	8.07	9.98
C_2G_2	9.59	11.69	11.31	7.29	9.97
C_2G_3	9.44	10.18	11.70	8.40	10.62
SEm (±)	0.43	0.30	0.56	0.29	0.27
CD (P=0.05)	1.266	0.871	NS	0.847	NS
F_1G_1	14.39	17.84	13.64	12.43	14.58
F_1G_2	14.32	16.85	17.01	10.35	14.63
F_1G_3	13.09	13.31	17.38	11.62	14.88
F_2G_1	9.69	7.78	7.02	6.89	7.85
F_2G_2	6.94	8.92	6.31	5.52	6.92
F_2G_3	10.41	9.64	9.39	7.70	9.29
F_3G_1	5.84	7.63	5.76	5.96	6.30
F_3G_2	6.34	6.62	6.26	7.15	6.59
F_3G_3	7.08	6.36	6.35	4.64	6.11
SEm (±)	0.53	0.37	0.69	0.36	0.33
CD (P=0.05)	1.551	1.067	2.002	1.037	0.962

Table 7c. Interaction effect of cropping system, top feeds and planting geometry on number of branches of top feeds during second year

Treatments	**Number of branches**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
$C_1F_1G_1$	15.89	14.84	11.83	13.71	14.07
$C_1F_1G_2$	12.63	14.70	12.48	11.59	12.85
$C_1F_1G_3$	12.18	14.19	15.58	10.19	13.03
$C_1F_2G_1$	11.71	4.70	5.95	6.98	7.34
$C_1F_2G_2$	6.97	8.47	6.04	6.14	6.91
$C_1F_2G_3$	12.10	6.49	10.23	7.57	9.10
$C_1F_3G_1$	5.07	8.34	5.26	5.67	6.09
$C_1F_3G_2$	6.83	6.54	6.71	6.44	6.63
$C_1F_3G_3$	8.56	7.37	5.33	5.00	6.57
$C_2F_1G_1$	12.89	20.83	15.44	11.16	15.08
$C_2F_1G_2$	16.01	18.99	21.53	9.11	16.41
$C_2F_1G_3$	14.00	12.43	19.19	13.05	16.74
$C_2F_2G_1$	7.66	10.87	8.09	6.80	8.35
$C_2F_2G_2$	6.91	9.36	6.58	4.90	6.94
$C_2F_2G_3$	8.71	12.78	8.56	7.84	9.47
$C_2F_3G_1$	6.62	6.91	6.26	6.25	6.51
$C_2F_3G_2$	5.85	6.71	5.81	7.86	6.56
$C_2F_3G_3$	5.60	5.34	7.36	4.29	5.65
SEm (±)	0.75	0.52	0.97	0.50	0.47
CD (P=0.05)	2.193	1.509	2.831	1.467	1.360

4.1.2.2. Leaf stem ratio

Tables 8a, 8b and 8c shows the effect of cropping system, top feeds and spacing on leaf stem ratio of top feeds during second year.

The data on mean leaf stem ratio of all the harvests during second year revealed that the treatment C_2 was significantly superior with respect to mean leaf stem ratio (0.74). Considering three different top feeds in the subplot, the mean leaf stem ratio was found to be significantly superior in F_1 (0.78). With respect to planting geometry of top feeds, paired system of planting was noticed to be superior (0.76). The interaction between cropping system and top feeds varied significantly in mean leaf stem ratio and higher value was noticed in C_2F_1 (0.82), however the interaction between cropping system and planting geometry also had significant influence on mean leaf stem ratio and significantly higher mean leaf stem ratio was noticed in C_2G_3 (0.79). Moreover, with respect to the interaction between top feeds and spacing, mean leaf stem ratio was found to be higher in F_1G_3 (0.81) and the value was comparable to F_1G_3. Considering the interaction between cropping system, top feeds and planting geometry, the treatment $C_2F_1G_2$ and $C_2F_1G_3$ had noticed with the highest mean value of 0.84 and it was on par with $C_2F_2G_3$

Regarding the data on individual harvests, intercropping had revealed significantly higher leaf stem ratio in second and fourth harvests (0.78 and 0.78 respectively). In the case of subplot factor, leaf stem ratio of each harvest varied significantly in all harvests and agathi was significantly superior in all harvests except first harvest (0.81, 0.80 and 0.84 respectively). *Erythrina* had higher leaf stem ratio in first harvest (0.68) and it was on par with agathi (0.67). In the case of sub-sub plot factor, significant difference was observed in all harvests and paired system showed significantly higher leaf stem ratio in second (0.77), third (0.79) and fourth (0.80) harvests, whereas growing top feeds at a spacing of 2 m x 0.5 m (G_2) was observed to be significantly superior (0.71) in first harvest.

Leaf stem ratio of top feeds significantly varied in response to interaction between cropping system and top feeds in all harvests except fourth harvest. At first harvest, C_2F_2 recorded higher leaf stem ratio of 0.70 and it was on par with C_1F_2 (0.66) and C_2F_1 (0.67). At second and third harvest C_2F_1 was observed to be superior

(0.86 and 0.85 respectively) and it was on par with C_2F_2 (0.84) in second harvest. Similarly, significant interaction between cropping system and planting geometry was noticed in leaf stem ratio of top feeds in all harvests except third harvest. C_2G_2 registered superior value in first harvest (0.72) and it was on par with C_1G_2 (0.69).Whereas in second and fourth harvests, C_2G_3 recorded significantly superior values of 0.86 and 0.87 respectively. Interaction between top feeds and their planting geometry was significant in all harvests. Regarding each harvest in the second year, F_3G_2 recorded the highest value of 0.76 in first cut and it was on par with F_2G_3 (0.74). However, F_1G_2 was superior in second harvest (0.86) and it was on par with F_1G_3 (0.84) and F_2G_1 (0.82). At third and fourth harvests F_1G_3 registered significantly higher values of 0.89 and 0.90 respectively.

The data on interaction between cropping system, top feeds and planting geometry on mean leaf stem ratio of top feeds revealed that at first harvest, $C_1F_3G_2$ recorded higher value (0.76) and it was on par with $C_1F_1G_1$, $C_1F_2G_2$, $C_1F_2G_3$, $C_2F_1G_2$, $C_2F_2G_3$, and $C_2F_3G_2$. However $C_2F_2G_3$ was superior in second cut and it was on par with $C_2F_1G_3$ and $C_2F_2G_1$.The treatment combination $C_2F_1G_3$ exhibited higher value of 0.94 in fourth harvest and it was on par with $C_2F_1G_1$.

Table 8a. Effect of cropping system, top feeds and planting geometry on leaf stem ratio of top feeds during second year

Treatments	Leaf stem ratio of top feeds				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
Cropping system (C)					
C_1: Sole crop (Top feeds)	0.66	0.69	0.70	0.67	0.69
C_2 : Intercrop (Bajra Napier Hybrid)	0.66	0.78	0.76	0.78	0.74
SEm (±)	0.004	0.004	0.012	0.010	0.005
CD (P=0.05)	NS	0.024	NS	0.059	0.014
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	0.67	0.81	0.80	0.84	0.78
F_2: *Erythrina* (*Erythrina indica*)	0.68	0.75	0.68	0.67	0.70
F_3: Drumstick (*Moringa oleifera*)	0.64	0.64	0.71	0.67	0.67
SEm (±)	0.01	0.02	0.03	0.01	0.01
CD (P=0.05)	0.027	0.049	0.008	0.032	0.021
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	0.62	0.72	0.65	0.67	0.67
G_2: 2 m x 0.5 m	0.71	0.71	0.74	0.70	0.72
G_3: Paired system	0.66	0.77	0.79	0.80	0.76
SEm (±)	0.01	0.01	0.03	0.01	0.01
CD (P=0.05)	0.025	0.027	0.009	0.019	0.014

NS: Not significant

Table 8b. Effect of C x F, C x G and F x G interactions on leaf stem ratio of top feeds during second year

Treatments	Leaf stem ratio of top feeds				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
C_1F_1	0.66	0.76	0.75	0.77	0.74
C_1F_2	0.67	0.65	0.67	0.63	0.66
C_1F_3	0.66	0.65	0.69	0.61	0.66
C_2F_1	0.67	0.86	0.85	0.91	0.82
C_2F_2	0.70	0.84	0.69	0.72	0.74
C_2F_3	0.61	0.63	0.73	0.72	0.67
SEm (±)	0.01	0.02	0.01	0.01	0.01
CD (P=0.05)	0.039	0.069	0.035	NS	0.029
C_1G_1	0.62	0.64	0.62	0.60	0.63
C_1G_2	0.69	0.74	0.71	0.67	0.70
C_1G_3	0.68	0.69	0.78	0.74	0.73
C_2G_1	0.63	0.80	0.96	0.74	0.72
C_2G_2	0.72	0.68	0.77	0.74	0.73
C_2G_3	0.63	0.86	0.81	0.87	0.79
SEm (±)	0.012	0.013	0.012	0.009	0.007
CD (P=0.05)	0.035	0.038	NS	0.027	0.020
F_1G_1	0.73	0.73	0.66	0.79	0.73
F_1G_2	0.65	0.86	0.84	0.84	0.80
F_1G_3	0.62	0.85	0.89	0.90	0.81
F_2G_1	0.60	0.83	0.65	0.63	0.68
F_2G_2	0.71	0.63	0.67	0.63	0.66
F_2G_3	0.74	0.78	0.73	0.76	0.76
F_3G_1	0.55	0.59	0.65	0.60	0.61
F_3G_2	0.76	0.63	0.71	0.65	0.69
F_3G_3	0.61	0.69	0.76	0.76	0.70
SEm (±)	0.015	0.016	0.015	0.033	0.008
CD (P=0.05)	0.043	0.046	0.045	0.011	0.025

NS: Not Significant

Table 8c. Interaction effect of cropping system, top feeds and planting geometry on leaf stem ratio of top feeds during second year

Treatments	Leaf stem ratio of top feeds				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
$C_1F_1G_1$	0.76	0.67	0.59	0.67	0.67
$C_1F_1G_2$	0.58	0.85	0.78	0.80	0.75
$C_1F_1G_3$	0.65	0.78	0.87	0.85	0.79
$C_1F_2G_1$	0.54	0.69	0.64	0.60	0.62
$C_1F_2G_2$	0.72	0.66	0.67	0.61	0.67
$C_1F_2G_3$	0.74	0.60	0.72	0.67	0.70
$C_1F_3G_1$	0.55	0.56	0.63	0.55	0.59
$C_1F_3G_2$	0.76	0.70	0.68	0.58	0.68
$C_1F_3G_3$	0.67	0.68	0.75	0.71	0.70
$C_2F_1G_1$	0.70	0.80	0.74	0.91	0.79
$C_2F_1G_2$	0.72	0.88	0.90	0.87	0.84
$C_2F_1G_3$	0.60	0.91	0.92	0.94	0.84
$C_2F_2G_1$	0.66	0.96	0.66	0.66	0.74
$C_2F_2G_2$	0.70	0.60	0.66	0.65	0.65
$C_2F_2G_3$	0.74	0.97	0.74	0.85	0.82
$C_2F_3G_1$	0.54	0.63	0.67	0.65	0.62
$C_2F_3G_2$	0.75	0.57	0.74	0.71	0.69
$C_2F_3G_3$	0.55	0.70	0.77	0.80	0.71
SEm (±)	0.021	0.022	0.022	0.016	0.012
CD (P=0.05)	0.061	0.065	NS	0.046	0.035

4.1.2.3. Green fodder yield

The data on effect of cropping system, top feeds and spacing on the green fodder yield of top feeds during second year are furnished in Tables 9a, 9b and 9c.

The data on total green fodder yield of top feeds during second year revealed that similar to first year, cropping system had significant influence on total green fodder yield and significantly higher green fodder yield was recorded under intercropping (18.91t ha^{-1} yr^{-1}) than sole cropping (14.23 t ha^{-1} yr^{-1}). Regarding subplot factor, agathi recorded significantly higher total green fodder yield of 22.34t ha^{-1} yr^{-1}. Whereas *Erythrina* had the least green fodder yield of 10.83 t ha^{-1} yr^{-1}. Among the three planting geometry in sub-sub plot, total green fodder yield was higher for G_2 (17.13 t ha^{-1} yr^{-1}) and it was comparable with G_3. Regarding the interaction between cropping system and top feeds, the total green fodder yield was significantly higher for C_2F_1 (25.73 t ha^{-1} yr^{-1}).With respect to interaction between cropping system and planting geometry, significantly higher total green fodder yield was noticed in C_2G_2 (20.34 t ha^{-1} yr^{-1}).Similarly the interaction between top feeds and planting geometry also varied significantly and F_1G_2 recorded higher total green fodder yield of 24.97 t ha^{-1} yr^{-1}. Significant interaction between cropping system, top feed and spacing was noticed with respect to total green fodder yield during second year and significantly higher total green fodder yield was noticed in $C_2F_1G_2$ (31.31 t ha^{-1} yr^{-1}).

The result revealed that green fodder yield varied significantly with cropping system in all harvests and intercropping recorded significantly higher green fodder yield in all harvests (3.94 t ha^{-1}, 5.06 t ha^{-1}, 5.60 t ha^{-1} and 4.29 t ha^{-1} respectively). Green fodder yield of different top feeds varied significantly in all harvests and it was observed that agathi was significantly superior in all the four cuts (4.64, 6.10, 6.591 and 5.00 t ha^{-1} respectively) and *Erythrina* recorded the lowest value. Regarding sub-sub plot factor, cultivating top feeds at 2 m x 0.5 m spacing (G_2) recorded higher green fodder yield in all the four harvests (3.58 t ha^{-1},4.58 t ha^{-1}, 5.07 t ha^{-1} and 3.90 t ha^{-1} respectively) and it was on par with paired system of planting (G_3).

The interaction between cropping system and spacing with respect to green fodder yield varied significantly in all harvests and significantly higher value was noticed in C_2F_1 (5.33 t ha^{-1},7.03 t ha^{-1},7.56 t ha^{-1} and 5.81 t ha^{-1} respectively). The result also revealed that interaction between cropping system and spacing followed the same trend as that in the first year, in which the green fodder yield varied significantly in all harvests except first harvest with significantly higher value in C_2G_2 (5.46, 6.08 and 4.63 t ha^{-1} respectively). Significant interaction between top feed and spacing was observed in green fodder yield of top feeds in all harvests except first harvest. It was observed that F_1G_2 had higher green fodder yield of 6.76 t ha^{-1}, 7.47 t ha^{-1} and 5.63t ha^{-1} respectively in second, third and fourth harvest and the values were on par with F_1G_3 in second harvest.

The interaction between cropping system, top feed and spacing followed the same trend as in first year. Significantly higher values were noticed in $C_2F_1G_2$ in first (6.33 t ha^{-1}) second (8.45t ha^{-1}), third (9.39t ha^{-1}) and fourth (7.13 t ha^{-1}) harvest.

Table 9a. Effect of cropping system, top feeds and planting geometry on green fodder yield of top feeds during second year, t ha^{-1}

Treatments	Green fodder yield of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
Cropping system (C)					
C_1: Sole crop (Top feeds)	2.97	3.80	4.15	3.30	14.23
C_2 :Intercrop (Bajra Napier Hybrid)	3.95	5.07	5.60	4.29	18.91
SEm (±)	0.12	0.06	0.08	0.03	0.09
CD (P=0.05)	0.722	0.386	0.466	0.199	0.565
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	4.65	6.10	6.59	5.00	22.34
F_2: *Erythrina* (*Erythrina indica*)	2.28	2.79	3.18	2.58	10.83
F_3: Drumstick (*Moringa oleifera*)	3.45	4.42	4.86	3.81	16.54
SEm (±)	0.12	0.16	0.04	0.08	0.13
CD (P=0.05)	0.374	0.513	0.137	0.251	0.435
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	3.25	4.17	4.60	3.58	15.60
G_2: 2 m x 0.5 m	3.58	4.58	5.07	3.90	17.13
G_3: Paired system	3.55	4.56	4.96	3.91	16.98
SEm (±)	0.09	0.09	0.07	0.07	0.09
CD (P=0.05)	0.270	0.275	0.189	0.194	0.565

Table 9b. Effect of C x F, C x G and F x G interactions on green fodder yield of top feeds during second year, t ha^{-1}

Treatments	Green fodder yield of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
C_1F_1	3.96	5.17	5.62	4.19	18.94
C_1F_2	2.40	3.05	3.39	2.77	11.61
C_1F_3	2.55	3.19	3.45	2.94	12.12
C_2F_1	5.33	7.03	7.56	5.81	25.73
C_2F_2	2.15	2.53	2.98	2.38	10.05
C_2F_3	4.36	5.64	6.27	4.68	20.96
SEm (±)	0.16	0.22	0.06	0.11	0.19
CD (P=0.05)	0.529	0.726	0.194	0.355	0.615
C_1G_1	2.78	3.58	3.96	3.16	13.49
C_1G_2	2.98	3.71	4.07	3.17	13.92
C_1G_3	3.15	4.12	4.44	3.57	15.27
C_2G_1	3.72	4.75	5.25	4.00	17.71
C_2G_2	4.18	5.46	6.08	4.63	20.34
C_2G_3	3.95	5.00	5.49	4.26	18.91
SEm (±)	0.13	0.13	0.11	0.09	0.23
CD (P=0.05)	NS	0.389	0.327	0.275	0.681
F_1G_1	4.25	5.51	5.94	4.53	20.22
F_1G_2	5.11	6.76	7.47	5.63	24.97
F_1G_3	4.58	6.03	6.37	4.84	21.82
F_2G_1	2.20	2.67	3.13	2.47	10.46
F_2G_2	2.24	2.76	3.13	2.52	10.65
F_2G_3	2.38	2.96	3.30	2.74	11.38
F_3G_1	3.30	4.33	4.75	3.73	16.11
F_3G_2	3.39	4.24	4.62	3.54	15.79
F_3G_3	3.68	4.68	5.22	4.16	17.73
SEm (±)	0.16	0.16	0.11	0.12	0.29
CD (P=0.05)	NS	0.476	0.327	0.336	0.834

Table 9c. Interaction effect of cropping system, top feeds and planting geometry on green fodder yield of top feeds during second year, t ha^{-1}

Treatments	**Green fodder yield of top feeds**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Total**
$C_1F_1G_1$	3.70	4.81	5.26	3.95	17.73
$C_1F_1G_2$	3.90	5.06	5.54	4.14	18.62
$C_1F_1G_3$	4.30	5.63	6.06	4.49	20.47
$C_1F_2G_1$	2.25	2.80	3.22	2.63	10.90
$C_1F_2G_2$	2.41	3.02	3.38	2.69	11.49
$C_1F_2G_3$	2.54	3.35	3.58	2.99	12.45
$C_1F_3G_1$	2.39	3.14	3.40	2.89	11.83
$C_1F_3G_2$	2.64	3.05	3.28	2.69	11.66
$C_1F_3G_3$	2.61	3.37	3.68	3.23	12.88
$C_2F_1G_1$	4.79	6.20	6.62	5.12	22.72
$C_2F_1G_2$	6.33	8.45	9.39	7.13	31.31
$C_2F_1G_3$	4.86	6.43	6.68	5.19	23.16
$C_2F_2G_1$	2.16	2.54	3.03	2.30	10.02
$C_2F_2G_2$	2.08	2.50	2.87	2.36	9.81
$C_2F_2G_3$	2.22	2.57	3.02	2.49	10.31
$C_2F_3G_1$	4.20	5.51	6.09	4.58	20.38
$C_2F_3G_2$	4.13	5.43	5.97	4.39	19.92
$C_2F_3G_3$	4.75	5.99	6.76	5.09	22.58
SEm (±)	0.23	0.23	0.16	0.16	0.57
CD (P=0.05)	0.062	0.674	0.463	0.476	1.180

4.1.2.4. Dry fodder yield

The Tables 10a, 10b and 10c present the effect of cropping system, top feeds and spacing on the dry fodder yield of top feeds during second year.

The data on total dry fodder yield of top feeds over four different harvests during second year revealed that intercropping (C_2) recorded significantly higher total dry fodder yield of 4.95 t ha^{-1} yr^{-1} than sole crop (3.61 t ha^{-1} yr^{-1}). With respect to three different top feeds, agathi had significantly superior value of 5.75 t ha^{-1} yr^{-1}, whereas the treatment F_2 (*Erythrina*) registered the lowest total dry fodder yield of 2.77 t ha^{-1} yr^{-1}. Regarding the planting geometry of top feeds, G_2 noticed to be higher in total dry fodder yield (4.4 t ha^{-1} yr^{-1}) and it was comparable to G_3. The interaction between cropping system and top feeds with respect to total dry fodder yield was found to be vary significantly and higher value was noticed in C_2F_1 (6.72 t ha^{-1} yr^{-1}). However considering the interaction between cropping system and planting geometry, significantly higher total dry fodder yield was registered by C_2G_2 (5.28 t ha^{-1} yr^{-1}). Significant interaction between top feeds and planting geometry was noticed with respect to total dry fodder yield and higher value was noticed in F_1G_2 (6.32 t ha^{-1} yr^{-1}). Considering the interaction between cropping system, top feeds and planting geometry, total dry fodder yield was superior in $C_2F_1G_2$ (8.04 t ha^{-1} yr^{-1}).

The data of dry fodder yield in each harvest revealed that, dry fodder yield of top feeds was significantly influenced by intercropping and cultivating top feeds along with Bajra Napier hybrid recorded significantly higher dry fodder yield in all harvests (1.04 t ha^{-1},1.33 t ha^{-1}, 1.45 t ha^{-1} and 1.12 t ha^{-1} respectively). Significant influence of top feed treatments on dry fodder yield was noticed in all harvests and cultivating agathi as main crop recorded significantly higher dry fodder yield in all harvests (1.20 t ha^{-1}, 1.56 t ha^{-1}, 1.69 t ha^{-1} and 1.3 t ha^{-1}respectively). With respect to planting geometry, dry fodder yield varied significantly with different spacing in all harvests except first harvest. In second and third harvest, G_2 recorded higher dry fodder yield (1.19 t ha^{-1} and 1.31 t ha^{-1}respectively) and it was on par with G_3. However in the fourth harvest, G_3 registered higher dry fodder yield of 1.02 t ha^{-1} and it was on par with G_2.

Regarding the interaction between cropping system and top feeds, dry fodder yield varied significantly in all the four harvests. As in the first year, C_2F_1 recorded significantly higher dry fodder yield in first (1.44 t ha^{-1}), second (1.83 t ha^{-1}), third (1.95 t ha^{-1}) and fourth (1.52 t ha^{-1}) harvests. Moreover, dry fodder yield was significantly influenced by the interaction between cropping system and spacing and significantly higher value was registered by C_2G_2 in second, third and fourth harvests (1.44 t ha^{-1}, 1.57 t ha^{-1}, and 1.18 t ha^{-1}respectively). In third harvest, C_2G_2 was on par with C_2G_3. The interaction effect of top feed and spacing varied significantly with respect to dry fodder yield in second, third and fourth harvests and higher values were noticed in F_1G_2 (1.70 t ha^{-1},1.89 t ha^{-1} and 1.44 t ha^{-1} respectively).

The interaction between cropping system, top feed and spacing was significant with respect to dry fodder yield in all harvests as in the first year with significantly higher values were noticed in $C_2F_1G_2$ (1.69 t ha^{-1},2.15 t ha^{-1}, 2.38 t ha^{-1} and 1.82 t ha^{-1} respectively).

Table 10a. Effect of cropping system, top feeds and planting geometry on dry fodder yield of top feeds during second year, t ha^{-1}

Treatments	Dry fodder yield of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
Cropping system (C)					
C_1: Sole crop (Top feeds)	0.74	0.96	1.06	0.84	3.61
C_2 :Intercrop(Bajra Napier Hybrid)	1.04	1.33	1.45	1.12	4.95
SEm (±)	0.04	0.01	0.02	0.01	0.03
CD (P=0.05)	0.227	0.084	0.100	0.045	0.182
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	1.21	1.56	1.69	1.30	5.75
F_2: *Erythrina* (*Erythrina indica*)	0.57	0.73	0.82	0.64	2.77
F_3: Drumstick (*Moringa oleifera*)	0.90	1.16	1.27	1.00	4.33
SEm (±)	0.02	0.02	0.01	0.02	0.03
CD (P=0.05)	0.052	0.077	0.036	0.065	0.085
G_3: Paired system	0.92	1.17	1.28	1.02	4.39
SEm (±)	0.02	0.02	0.02	0.02	0.04
CD (P=0.05)	NS	0.061	0.051	0.052	0.122

NS: Not Significant

Table 10b. Effect of C x F, C x G and F x G interactions on dry fodder yield of top feeds during second year, t ha^{-1}

Treatments	Dry fodder yield of top feeds				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Total**
C_1F_1	0.97	1.29	1.42	1.09	4.77
C_1F_2	0.60	0.77	0.85	0.69	2.91
C_1F_3	0.66	0.83	0.92	0.75	3.17
C_2F_1	1.44	1.83	1.95	1.52	6.72
C_2F_2	0.55	0.68	0.80	0.59	2.63
C_2F_3	1.14	1.49	1.61	1.26	5.50
SEm (±)	0.02	0.03	0.02	0.03	0.04
CD (P=0.05)	0.074	0.109	0.051	0.092	0.120
C_1G_1	0.71	0.92	0.99	0.81	3.42
C_1G_2	0.73	0.94	1.06	0.81	3.53
C_1G_3	0.80	1.03	1.15	0.91	3.90
C_2G_1	1.00	1.25	1.39	1.05	4.68
C_2G_2	1.10	1.44	1.57	1.18	5.28
C_2G_3	1.04	1.31	1.40	1.13	4.88
SEm (±)	0.03	0.03	0.03	0.03	0.06
CD (P=0.05)	NS	0.086	0.072	0.074	0.172
F_1G_1	1.10	1.43	1.48	1.16	5.17
F_1G_2	1.29	1.70	1.89	1.44	6.32
F_1G_3	1.22	1.55	1.68	1.31	5.74
F_2G_1	0.57	0.69	0.82	0.63	2.71
F_2G_2	0.55	0.71	0.83	0.62	2.70
F_2G_3	0.60	0.78	0.83	0.68	2.88
F_3G_1	0.88	1.14	1.26	1.00	4.27
F_3G_2	0.89	1.16	1.21	0.92	4.18
F_3G_3	0.93	1.19	1.33	1.09	4.54
SEm (±)	0.04	0.04	0.03	0.03	0.07
CD (P=0.05)	NS	0.105	0.088	0.090	0.211

NS: Not Significant

Table 10c. Interaction effect of cropping system, top feeds and planting geometry on dry fodder yield of top feeds during second year, t ha^{-1}

Treatments	Dry fodder yield of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
$C_1F_1G_1$	0.93	1.24	1.29	1.01	4.47
$C_1F_1G_2$	0.90	1.24	1.41	1.06	4.61
$C_1F_1G_3$	1.09	1.38	1.58	1.19	5.23
$C_1F_2G_1$	0.57	0.69	0.80	0.67	2.73
$C_1F_2G_2$	0.57	0.76	0.85	0.68	2.86
$C_1F_2G_3$	0.64	0.86	0.89	0.73	3.12
$C_1F_3G_1$	0.63	0.82	0.87	0.74	3.06
$C_1F_3G_2$	0.70	0.82	0.91	0.68	3.11
$C_1F_3G_3$	0.66	0.86	0.99	0.82	3.33
$C_2F_1G_1$	1.28	1.61	1.68	1.30	5.88
$C_2F_1G_2$	1.69	2.15	2.38	1.82	8.04
$C_2F_1G_3$	1.35	1.72	1.77	1.42	6.26
$C_2F_2G_1$	0.57	0.70	0.83	0.59	2.69
$C_2F_2G_2$	0.53	0.66	0.80	0.56	2.55
$C_2F_2G_3$	0.55	0.69	0.77	0.63	2.64
$C_2F_3G_1$	1.13	1.45	1.64	1.26	5.48
$C_2F_3G_2$	1.07	1.50	1.52	1.16	5.26
$C_2F_3G_3$	1.21	1.53	1.67	1.35	5.75
SEm (±)	0.05	0.05	0.04	0.04	0.10
CD (P=0.05)	0.151	0.148	0.124	0.128	0.298

4.1.2.5. Dry matter content

The data on effect of cropping system, top feeds and spacing on dry matter content of top feeds during second year are furnished in Tables 11a, 11b and 11c.

The results revealed that the mean dry matter content of top feeds during the second year varied significantly varied in response to cropping system with C_2 recording significantly higher value (26.21%). However mean dry matter content did not vary significantly with respect to top feeds and their planting geometry. Similarly the interaction between cropping system and top feeds and cropping system and planting geometry did not vary significantly with respect to mean dry matter content. However among the treatment combinations on interaction between top feeds and geometry, it was observed that F_3G_2 had the highest mean dry matter content (26.54 %) and it was on par with F_3G_1 and F_1G_3. Regarding the interaction between cropping system, top feeds and planting geometry, the mean dry matter content was higher in $C_2F_1G_3$ (27.02%) and the value was comparable to ..... $C_2F_3G_1$, $C_2F_3G_2$, $C_2F_2G_1$ and $C_1F_3G_2$.

The data on dry matter content of the individual harvests during second year revealed that in all harvests significantly higher values were noticed when top feeds were intercropped with Bajra Napier hybrid (26.44 %, 26.49 %, 26.15 % and 25.90 % respectively). Regarding different top feeds, dry matter content differed significantly in third and fourth harvests and significantly higher value was observed in drumstick (26.22 % and 26.17 % respectively). With respect to planting geometry of top feeds, significant variation was observed with respect to dry matter in third and fourth harvest and significantly higher value was noticed in G_2 (26.15 %), whereas G_3 registered higher dry matter content in fourth harvest (25.94 %) and it was on par with G_1 (25.84 %)

The data on dry matter content of four different harvests during second year revealed that the values significantly varied in third and fourth harvests. In third harvest, the treatment combination C_2F_2 recorded higher dry matter content of 26.94 per cent and it was on par with C_1F_3 (26.70 %). However C_2F_3 was superior in fourth harvest (26.81%). Regarding the interaction between cropping system and geometry, significant interaction was noticed in dry matter content of top feeds in third and fourth harvests. At third harvest, C_2G_1 was significantly superior (26.64 %), whereas C_2G_3 registered higher value in fourth harvest (26.40 %) and it was on par with C_2G_1 (26.13 %).The interaction effect of top feeds and spacing was found to be significant in all harvests except first harvest. At second and third harvests, higher dry matter content of 27.18 per cent and 26.58 per cent were noticed in F_3G_2 and in second harvest, it was on par with F_2G_1, F_2G_3 and F_3G_1.and F_1G_3. At third harvest, the values of F_3G_2 and F_2G_2 were comparable. However, F_1G_3 recorded higher dry matter content in fourth harvest (26.92%) and it was on par with F_3G_1 (26.53 %). Significant interaction between cropping system, top feeds and planting geometry were noticed in dry matter content of third and fourth harvests. At third harvest, higher value of 27.8 per cent was noticed in $C_2F_2G_2$ and it was on par with $C_1F_3G_2$.and $C_2F_2G_1$. However, $C_2F_3G_3$ registered the higher value (27.45 %) in fourth harvest and it was on par with $C_2F_1G_3$ (27.4 %).

Table 11a. Effect of cropping system, top feeds and planting geometry on dry matter content of top feeds during second year, per cent

Treatments	**Dry matter content of top feeds**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
Cropping system (C)					
C_1: Sole crop (Top feeds)	25.24	25.58	25.65	25.47	25.44
C_2 :Intercrop(Bajra Napier Hybrid)	26.44	26.49	26.15	25.90	26.21
SEm (±)	0.15	0.05	0.07	0.02	0.03
CD (P=0.05)	0.940	0.300	0.455	0.123	0.178
Top feeds (F)					
F_1: Agathi (*Sesbania grandiflora*)	25.89	25.58	25.54	26.01	25.68
F_2: *Erythrina* (*Erythrina indica*)	25.53	26.20	25.93	24.89	25.60
F_3: Drumstick (*Moringa oleifera*)	26.10	26.32	26.22	26.17	26.19
SEm (±)	0.48	0.58	0.06	0.05	0.17
CD (P=0.05)	NS	NS	0.195	0.166	NS
Planting geometry of top feeds (G)					
G_1: 2 m x 1 m	26.19	26.16	25.79	25.84	25.96
G_2: 2 m x 0.5 m	25.34	26.12	26.15	25.28	25.73
G_3: Paired system	25.99	25.81	25.75	25.94	25.79
SEm (±)	0.55	0.23	0.06	0.10	0.10
CD (P=0.05)	NS	NS	0.162	0.281	NS

Table 11b. Effect of C x F, C x G and F x G interactions on dry matter content of top feeds during second year, per cent

Treatments	**Dry matter content of top feeds**				
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Mean**
C_1F_1	24.67	25.14	25.32	25.88	25.16
C_1F_2	25.06	25.45	24.91	25.02	25.03
C_1F_3	26.00	26.15	26.70	25.53	26.13
C_2F_1	27.11	26.02	25.76	26.13	26.19
C_2F_2	26.01	26.95	26.94	24.76	26.18
C_2F_3	26.20	26.48	25.74	26.81	26.26
SEm (±)	0.67	0.81	0.09	0.07	0.23
CD (P=0.05)	NS	NS	0.276	0.234	NS
C_1G_1	25.56	25.69	24.93	25.55	25.36
C_1G_2	24.61	25.72	26.08	25.39	25.44
C_1G_3	25.55	25.34	25.92	25.48	25.52
C_2G_1	26.82	26.63	26.64	26.13	26.55
C_2G_2	26.07	26.53	26.23	25.17	26.02
C_2G_3	26.42	26.29	25.58	26.40	26.05
SEm (±)	0.77	0.33	0.08	0.14	0.15
CD (P=0.05)	NS	NS	0.229	0.397	NS
F_1G_1	25.93	25.98	24.93	25.50	25.53
F_1G_2	25.05	25.07	25.37	25.60	25.21
F_1G_3	26.69	25.69	26.33	26.92	26.29
F_2G_1	26.04	26.32	26.14	25.50	25.96
F_2G_2	24.78	26.03	26.51	24.30	25.44
F_2G_3	25.78	26.25	25.13	24.86	25.41
F_3G_1	26.61	26.18	26.29	26.53	26.37
F_3G_2	26.20	27.28	26.58	25.95	26.54
F_3G_3	25.49	25.50	25.80	26.04	25.68
SEm (±)	0.94	0.40	0.10	0.17	0.18
CD (P=0.05)	NS	1.176	0.281	0.486	0.522

Table 11c. Interaction effect of cropping system, top feeds and planting geometry on dry matter content of top feeds during second year, per cent

Treatments	Dry matter content of top feeds				
	Harvest I	Harvest II	Harvest III	Harvest IV	Mean
$C_1F_1G_1$	25.02	25.96	24.45	25.54	25.20
$C_1F_1G_2$	23.34	24.75	25.39	25.65	24.75
$C_1F_1G_3$	25.64	24.71	26.11	26.45	25.55
$C_1F_2G_1$	25.53	25.05	24.75	25.50	25.04
$C_1F_2G_2$	23.95	25.51	25.23	25.10	24.89
$C_1F_2G_3$	25.70	25.80	24.76	24.45	25.14
$C_1F_3G_1$	26.13	26.05	25.60	25.60	25.84
$C_1F_3G_2$	26.54	26.90	27.61	25.44	26.68
$C_1F_3G_3$	25.31	25.50	26.90	25.54	25.88
$C_2F_1G_1$	26.83	26.00	25.40	25.45	25.87
$C_2F_1G_2$	26.75	25.40	25.34	25.55	25.68
$C_2F_1G_3$	27.74	26.67	26.54	27.40	27.02
$C_2F_2G_1$	26.55	27.60	27.53	25.50	26.88
$C_2F_2G_2$	25.60	26.54	27.80	23.50	25.98
$C_2F_2G_3$	25.87	26.70	25.50	25.27	25.67
$C_2F_3G_1$	27.08	26.30	26.99	27.45	26.91
$C_2F_3G_2$	25.86	27.65	25.54	26.45	26.39
$C_2F_3G_3$	25.66	25.50	24.70	26.54	25.47
SEm (±)	1.34	0.57	0.14	0.24	0.25
CD (P=0.05)	NS	NS	0.397	0.688	0.739

4.1.2.6. Root weight and root volume of top feeds

The result of effect of cropping system, top feeds and spacing on root weight and root volume of top feeds after two years are presented in Tables 12a, 12b and 12c.

The results revealed that intercropping had significant effect on root weight. Growing top feeds along with Bajra Napier hybrid increased the root weight and root volume. After two years, root fresh weight under intercropping was 1369.85 g per plant and dry weight was 204.25 g per plant. The root volume was also observed to be significantly higher for C_2 (1216.95 cm^3). Among the three top feeds, agathi registered significantly the highest root fresh weight (1549.94 g per plant), root dry weight (234.47 g per plant) and root volume (1429.35cm^3 per plant). The treatment G_3 was observed to be the best planting geometry with respect to root fresh weight (1359.41 g per plant), dry weight (177.79 g per plant) and root volume (1224.06 cm^3).

Among different treatment combinations, significant interaction between cropping system and top feeds was observed in root dry weight with significantly higher dry weight noticed in C_2F_1 (312.48 g per plant). However the effect on root fresh weight and root volume were not significant. Root weight and volume were not significant with respect to the interaction between cropping system and spacing. There was significant interaction between top feeds and spacing with respect to root fresh weight, root dry weight and root volume. The highest root fresh weight of 1821.23 g per plant and dry weight of 273.28 g per plant were recorded in F_1G_3. The value of root dry weight was on par with F_1G_2 (233.41 g per plant). Moreover F_1G_3 also observed to be significantly the highest with respect to root volume (1682.99 cm^3 per plant).

Significant interaction between cropping system, top feeds and planting geometry was noticed in root weight and root volume of top feeds after two years. $C_2F_1G_3$ registered significantly the highest root fresh weight (2454.98 g per plant), root dry weight (405.91 g per plant) and root volume (2342.77cm^3 per plant).

Table 12a. Effect of cropping system, top feeds and planting geometry on root weight and root volume of top feeds (after two years)

Treatments	Root weight (g per plant)		Root volume (cm^3 per plant)
	Fresh weight	Dry weight	
Cropping system (C)			
C_1: Sole crop (Top feeds)	952.71	103.71	885.64
C_2 :Intercrop (Bajra Napier Hybrid)	1369.85	204.25	1216.95
SEm (±)	20.17	8.80	9.25
CD (P=0.05)	124.423	54.284	57.048
Top feeds (F)			
F_1: Agathi (*Sesbania grandiflora*)	1549.94	234.47	1429.35
F_2: *Erythrina* (*Erythrina indica*)	850.08	84.42	751.81
F_3: Drumstick (*Moringa oleifera*)	1083.83	143.04	972.73
SEm (±)	102.47	12.73	97.61
CD (P=0.05)	333.759	41.461	317.927
Planting geometry of top feeds (G)			
G_1: 2 m x 1 m	1076.66	135.24	988.05
G_2: 2 m x 0.5 m	1047.78	148.90	941.78
G_3: Paired system	1359.41	177.79	1224.07
SEm (±)	68.78	9.93	64.29
CD (P=0.05)	200.819	28.993	187.704

Table 12b. Effect of C x F, C x G and F x G interactions on root weight and root volume of top feeds (after two years)

Treatments	Root weight of top feeds (g per plant)		Root volume (cm^3 per plant)
	Fresh weight	Dry weight	
C_1F_1	1191.50	156.46	1100.23
C_1F_2	860.06	70.84	811.91
C_1F_3	806.57	83.82	744.80
C_2F_1	1908.39	312.48	1758.47
C_2F_2	840.09	98.00	691.71
C_2F_3	1361.09	202.26	1200.66
SEm (±)	144.91	18.00	138.04
CD (P=0.05)	NS	58.635	NS
C_1G_1	877.47	99.91	777.15
C_1G_2	1167.32	115.14	1063.30
C_1G_3	813.34	96.07	816.48
C_2G_1	1275.85	170.57	1198.95
C_2G_2	1551.50	240.45	1384.83
C_2G_3	1282.21	201.73	1067.07
SEm (±)	97.28	14.04	90.92
CD (P=0.05)	NS	NS	NS
F_1G_1	1368.76	196.71	1299.48
F_1G_2	1459.85	233.41	1305.59
F_1G_3	1821.23	273.29	1682.99
F_2G_1	591.20	47.00	478.19
F_2G_2	1062.12	110.48	949.27
F_2G_3	896.91	95.79	827.95
F_3G_1	1270.02	162.01	1186.46
F_3G_2	1194.88	149.62	1039.94
F_3G_3	786.58	117.50	691.79
SEm (±)	119.14	17.20	111.36
CD (P=0.05)	347.828	50.218	325.112

NS: Not Significant

Table 12 c. Interaction effect of cropping system, top feeds and planting geometry on root weight and root volume of top feeds (after two years)

Treatments	**Root weight of top feeds (g per plant)**		**Root volume (cm^3 per plant)**
	Fresh weight	**Dry weight**	
$C_1F_1G_1$	1129.37	152.65	933.25
$C_1F_1G_2$	1,187.48	140.66	1023.20
$C_1F_1G_3$	1257.66	176.07	1344.23
$C_1F_2G_1$	325.69	27.09	326.06
$C_1F_2G_2$	1452.88	119.71	1352.34
$C_1F_2G_3$	801.60	65.71	757.32
$C_1F_3G_1$	1177.34	119.98	1072.12
$C_1F_3G_2$	861.61	85.06	814.37
$C_1F_3G_3$	380.75	46.43	347.90
$C_2F_1G_1$	1608.15	240.76	1665.70
$C_2F_1G_2$	1662.03	290.76	1266.95
$C_2F_1G_3$	2454.98	405.91	2342.77
$C_2F_2G_1$	856.71	66.90	630.32
$C_2F_2G_2$	671.35	101.24	546.21
$C_2F_2G_3$	992.21	125.86	898.59
$C_2F_3G_1$	1362.70	204.04	1300.81
$C_2F_3G_2$	1528.16	214.18	1265.51
$C_2F_3G_3$	1192.40	188.57	1035.67
SEm (±)	168.48	24.33	157.48
CD (P=0.05)	491.903	71.019	459.778

4.1.3 Growth and yield attributes of Bajra Napier hybrid during first year

The observations on growth and yield attributes of Bajra Napier hybrid in terms of plant height, leaf stem ratio, number of tillers, tussock diameter, green fodder yield and dry fodder yield during first year were recorded and the results are presented below.

4.1.3.1 Plant height

The result on the effect of top feeds and spacing on plant height of Bajra Napier hybrid in six different harvests during first year are furnished in Tables 13a and 13b.

The results revealed that the mean plant height of Bajra Napier hybrid over all the six harvests varied significantly with different top feeds and F_2 recorded significantly greater mean plant height of 186.51cm. However the shortest height (171.67 cm) was noticed by F_3 in the first year. Among the three planting geometry of top feeds, maximum mean plant height (Bajra Napier hybrid) was noticed for G_2 (185.10 cm) and the value was comparable with G_1. The plant height of Bajra Napier hybrid was not significantly influenced by the interaction between top feeds and planting geometry.

The data regarding plant height in each harvest, it was revealed that the plant height of Bajra Napier hybrid varied significantly in all the six harvests except fifth harvest. Treatment F_2 recorded significantly the tallest plant height in first (183.63 cm), second (167.36 cm), third (190.94 cm), fourth (197.742 cm) and sixth (168.00 cm) harvest. But the values were comparable with F_1 in third and fourth harvest (182.8 cm and 193.818 cm respectively).

Regarding influence of planting geometry on plant height of Bajra Napier hybrid in each harvest, it did not show any significant difference during third and fifth harvests. Whereas in remaining harvests (first, second and fourth), taller plant were noticed in G_2 (177.14cm, 168.46 cm and 198.98 cm respectively) and the values were on par with G_1 (176.05 cm, 167.10 cm and 196.11 cm respectively). Among the three planting geometry, G_3 (paired system) recorded significantly the shortest plant in all the harvests.

Table 13a: Effect of top feeds and planting geometry on plant height of Bajra Napier hybrid during first year, cm

Treatments	Plant height						
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI	Mean
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	167.55	158.31	182.80	193.82	209.61	160.79	178.81
F_2: *Erythrina* (*Erythrina indica*)	183.63	167.36	190.94	197.74	211.42	168.00	186.52
F_3: Drumstick (*Moringa oleifera*)	166.29	153.04	175.12	183.92	199.44	152.18	171.67
SEm (±)	2.20	1.50	2.34	2.51	2.58	1.73	1.40
CD (P=0.05)	8.854	6.027	9.427	10.126	NS	6.968	5.655
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	176.05	167.10	185.46	196.11	207.03	164.78	182.76
G_2: 2 m x 0.5 m	177.14	168.46	184.57	198.98	209.55	171.93	185.10
G_3: Paired system	164.29	143.16	178.83	180.40	203.88	144.27	169.14
SEm (±)	2.54	2.60	3.41	2.60	2.36	1.74	1.19
CD (P=0.05)	7.923	8.093	NS	8.108	NS	5.431	3.696

Table 13b. Interaction effect of top feeds and planting geometry on plant height of Bajra Napier hybrid during first year, cm

Treatments	**Plant height**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	172.46	167.28	192.94	198.74	203.95	167.27	183.77
$F1G_2$	175.43	165.48	179.81	207.08	206.84	167.58	183.70
F_1G_3	154.78	142.16	175.66	175.64	218.05	147.54	168.97
F_2G_1	187.90	177.89	182.50	205.97	217.43	177.27	191.49
F_2G_2	186.53	180.68	191.35	197.61	218.89	182.27	192.89
F_2G_3	176.46	143.51	198.97	189.65	197.94	144.47	175.17
F_3G_1	167.79	156.12	180.94	183.61	199.72	149.79	173.00
F_3G_2	169.45	159.21	182.57	192.24	202.93	165.93	178.72
F_3G_3	161.64	143.80	161.85	175.90	195.67	140.82	163.28
SEm (±)	3.80	2.59	4.05	4.35	4.46	2.99	2.43
CD (P=0.05)	NS	NS	19.438	NS	14.146	10.318	NS

The interaction between top feeds and planting geometry did not show any significant difference in all harvests except the third, fourth and fifth. In third harvest, the tallest plant (198.97 cm) was noticed in F_2G_3 and the value was comparable with F_1G_2, F_1G_3, F_2G_1, F_2G_2, F_1G_1, F_3G_1 and F_3G_2. However F_2G_2 recorded higher values in fifth (218.99 cm) and sixth (182.27 cm) harvest it was on par with F_1G_2, F_1G_3 and F_2G_1 in fifth harvest and with F_2G_1 in sixth harvest.

4.1.3.2. Leaf stem ratio

The effect of top feeds and its planting geometry on leaf stem ratio of Bajra Napier hybrid during first year were analyzed and the results are presented in Tables 14a and 14 b.

The results revealed that in first year, the higher average leaf stem ratio of 2.10 was noticed when Bajra Napier hybrid intercropped with *Erythrina*. However considering planting geometry, G_2 registered significantly higher mean leaf stem ratio of 2.13. Regarding the interaction between top feeds and planting geometry, F_2G_2 recorded the highest leaf stem ratio (2.32) and it was comparable with F_2G_1 (2.23).

Regarding individual harvest, *Erythrina* recorded significantly higher leaf stem ratio in second, third, fifth and sixth harvests (1.77, 1.89, 2.85 and 1.87 respectively) and it was on par with agathi in sixth harvest (1.71).

The data also revealed that the planting geometry of top feed had significant effect on leaf stem ratio of Bajra Napier hybrid and higher value was noticed in G_2 in all harvests (1.96, 1.86, 1.90, 2.40 and 2.91 respectively from first to fifth harvest) except sixth harvest. However, G_1 was significantly higher in sixth harvest (1.86). Considering all the harvests, the lowest leaf stem ratio was in G_3. The study revealed a positive interaction between top feeds and spacing on leaf stem ratio of Bajra Napier hybrid. Among the treatment combinations, F_2G_2 recorded higher leaf stem ratio of 2.11 in third harvest and it was on par with F_2G_1 (2.02). However at fifth harvest, F_2G_2 recorded higher leaf stem ratio (3.21) and it was on par with F_1G_1 and F_2G_1. The treatment combination F_2G_1 topped in leaf stem ratio at sixth harvest (2.21) and it remained comparable with F_1G_1 and F_2G_2.

Table 14a. Effect of top feeds and planting geometry on leaf stem ratio of Bajra Napier hybrid during first year

Treatments	**Leaf stem ratio**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	1.56	1.50	1.69	2.34	2.57	1.71	1.90
F_2: *Erythrina* (*Erythrina indica*)	1.94	1.77	1.89	2.25	2.85	1.87	2.10
F_3: Drumstick (*Moringa oleifera*)	1.70	1.39	1.53	2.33	2.34	1.33	1.77
SEm (±)	0.09	0.06	0.02	0.04	0.05	0.05	0.02
CD (P=0.05)	NS	0.025	0.089	NS	0.205	0.203	0.094
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	1.77	1.46	1.79	2.55	2.78	1.86	2.04
G_2: 2 m x 0.5 m	1.96	1.86	1.90	2.40	2.91	1.75	2.13
G_3: Paired system	1.46	1.34	1.42	1.96	2.07	1.30	1.59
SEm (±)	0.05	0.07	0.03	0.06	0.05	0.05	0.02
CD (P=0.05)	0.169	0.219	0.084	0.184	0.154	0.146	0.068

NS: Not Significant

Table 14b. Interaction effect of top feeds and planting geometry on leaf stem ratio of Bajra Napier hybrid during first year

Treatments	**Leaf stem ratio**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	1.59	1.45	1.81	2.67	2.92	2.01	2.08
$F1G_2$	1.85	1.87	1.98	2.30	2.84	1.88	2.12
F_1G_3	1.23	1.18	1.28	2.04	1.95	1.25	1.49
F_2G_1	1.99	1.66	2.02	2.43	3.09	2.21	2.23
F_2G_2	2.16	2.14	2.11	2.32	3.21	1.97	2.32
F_2G_3	1.67	1.52	1.56	2.00	2.25	1.44	1.74
F_3G_1	1.74	1.26	1.55	2.56	2.33	1.37	1.80
F_3G_2	1.88	1.56	1.61	2.58	2.68	1.41	1.96
F_3G_3	1.47	1.33	1.43	1.85	2.00	1.20	1.55
SEm (±)	0.15	0.10	0.04	0.07	0.09	0.09	0.04
CD (P=0.05)	NS	NS	0.156	NS	0.294	0.280	0.131

NS: Not Significant

4.1.3.3. Number of tillers per hill

The data on effect of different top feeds and planting geometry on number of tillers per hill of Bajra Napier hybrid during first year are presented in Tables 15a and 15b.

The results revealed that the mean number of tillers over all the six harvests were significantly higher in F_2 (24.18). Regarding planting geometry of top feeds, the mean number of tillers in first year was the highest in G_2 (23.36) and it was comparable with G_1. The interaction between top feeds and planting geometry did not record any significant effect on average number of tillers of Bajra Napier hybrid in any of the harvests.

Regarding individual harvests, number of tillers of Bajra Napier hybrid did not show any significant effect on top feeds in all harvests except third harvest wherein F_2 recorded significantly more number of tillers in third harvest (25.22). Moreover, number of tillers significantly varied with planting geometry in all harvests except fourth and sixth harvest. Growing top feeds at a geometry of 2 m x 0.5 m (G_2) recorded the highest number of tillers in first (24.19), second (21.26), third (23.16) and fifth (25.11) harvest. And the values were comparable with G_1 (2 m x 1 m).

Table 15a. Effect of top feeds and planting geometry on number of tillers per hill of Bajra Napier hybrid during first year

Treatments	**Number of tillers per hill**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	20.53	18.46	17.01	21.80	26.78	14.18	19.79
F_2: *Erythrina* (*Erythrina indica*)	24.53	21.83	25.22	23.67	30.33	19.49	24.18
F_3: Drumstick (*Moringa oleifera*)	20.56	17.01	19.11	18.31	22.30	14.63	18.65
SEm (±)	1.03	1.60	1.26	1.53	2.48	1.89	0.67
CD (P=0.05)	NS	NS	5.059	NS	NS	NS	2.687
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	22.96	19.93	21.80	20.54	23.99	17.84	22.00
G_2: 2 m x 0.5 m	24.19	21.26	23.16	24.34	25.11	16.85	23.36
G_3: Paired system	18.47	16.11	16.37	18.90	17.80	13.61	17.27
SEm (±)	1.35	0.92	1.81	1.94	2.13	1.13	0.08
CD (P=0.05)	4.211	2.861	5.637	NS	6.633	NS	2.744

NS: Not Significant

Table 15b. Interaction effect of top feeds and planting geometry on number of tillers per hill of Bajra Napier hybrid during first year

Treatments	**Number of tillers per hill**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	20.75	19.06	19.96	18.94	29.77	12.63	20.18
$F1G_2$	23.37	20.65	16.58	26.66	29.84	17.54	22.44
F_1G_3	17.47	15.67	14.48	19.80	20.72	12.39	16.76
F_2G_1	25.36	22.40	26.54	24.34	32.97	22.13	25.63
F_2G_2	27.76	24.75	32.58	26.61	36.12	20.16	28.00
F_2G_3	20.45	18.33	16.52	20.05	21.91	16.19	18.91
F_3G_1	22.76	18.34	18.91	18.33	23.99	18.76	20.18
F_3G_2	21.44	18.38	20.32	19.74	25.11	12.87	19.64
F_3G_3	17.48	14.32	18.10	16.87	17.80	12.25	16.14
SEm (±)	1.78	2.77	2.17	2.66	4.29	3.28	1.15
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

NS: Not Significant

4.1.3.4. Tussock diameter

Tables 16a and 16b present the effect of top feeds and planting geometry on tussock diameter of Bajra Napier hybrid during first year.

The data on tussock diameter of Bajra Napier hybrid with respect to different top feeds in the main field revealed that the treatment F_2 recorded significantly higher mean tussock diameter (70.55 cm) in the first year. Among the three planting geometry, G_2 recorded the highest value of 69.98 cm and it was on par with G_1. The data revealed that F x G interaction was not significant with respect to mean tussock diameter of Bajra Napier hybrid.

The results also revealed that, there was significant effect for growing Bajra Napier hybrid as an intercrop along with the top feeds, in all harvests except the third and fifth harvests. Moreover, the treatment F_2 also recorded significantly higher tussock diameter in first (69.38 cm), second (65.20 cm) and fifth (89.51 cm) harvest. However in the fourth harvest, the treatment F_2 (66.68 cm) was comparable with F_1 (63.07 cm).

Significant influence of planting geometry on tussock diameter was observed in all harvests, excluding first and third harvests. Regarding individual harvests, the treatment G_2 recorded significantly higher tussock diameter in fourth (67.73 cm) harvest. The same treatment topped in second harvest also (64.30 cm) and it was on par with G_1 (61.79 cm). However in fifth and sixth harvests, G_1 had the highest value (89.49 cm and 66.68 cm respectively) and it was comparable with G_2 (88.99 cm and 64.30 cm respectively). Moreover the F x G interaction was not significant with respect to tussock diameter of Bajra Napier hybrid in all the harvests except third and fifth. At third harvest, the treatment combination F_3G_3 recorded the highest value of 70.85 cm and it was on par with F_2G_1, F_2G_2 and F_3G_2.Whereas F_2G_2 recorded the highest value in fifth harvest (95.63 cm) and it was comparable with F_3G_1, F_2G_1 and F_1G_2.

Table 16a. Effect of top feeds and planting geometry on tussock diameter of Bajra Napier hybrid during first year, cm

Treatments	**Tussock diameter**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	62.95	60.50	59.93	63.07	81.19	64.83	65.41
F_2: *Erythrina* (*Erythrina indica*)	69.38	65.20	65.10	66.68	89.51	67.42	70.55
F_3: Drumstick (*Moringa oleifera*)	61.42	59.20	66.58	56.34	79.34	63.67	64.43
SEm (±)	0.97	0.88	1.33	1.38	1.97	2.06	0.49
CD (P=0.05)	3.893	3.560	NS	5.562	7.956	NS	1.991
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	64.59	61.79	63.97	61.32	89.49	66.68	68.09
G_2: 2 m x 0.5 m	66.77	64.30	65.53	67.73	88.99	64.30	69.98
G_3: Paired system	62.38	58.82	62.10	57.04	71.56	60.02	62.32
SEm (±)	1.14	1.28	1.77	1.73	1.36	1.40	0.69
CD (P=0.05)	NS	3.976	NS	5.390	3.927	4.373	2.152

Table 16b. Interaction effect of top feeds and planting geometry on tussock diameter of Bajra Napier hybrid during first year, cm

Treatments	**Tussock Diameter**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	62.61	60.95	63.71	59.42	87.49	66.11	66.71
$F1G_2$	64.49	62.58	58.81	70.30	89.22	67.00	68.74
F_1G_3	61.74	57.97	57.28	59.48	66.86	61.38	60.79
F_2G_1	68.96	64.82	67.71	68.86	90.13	69.35	71.64
F_2G_2	71.95	68.12	69.40	71.20	95.63	68.30	74.10
F_2G_3	67.22	62.67	58.17	59.98	82.77	64.61	65.90
F_3G_1	62.21	59.60	60.49	55.68	90.85	66.68	65.92
F_3G_2	63.87	62.19	68.38	61.68	82.11	64.30	67.09
F_3G_3	58.19	55.81	70.85	51.66	65.05	60.02	60.27
SEm (±)	1.67	1.53	2.31	2.39	3.42	3.56	0.86
CD (P=0.05)	NS	NS	10.176	NS	7.903	NS	NS

NS: Not Significant

4.1.3.5. Green fodder yield

The data on effect of different top feeds and planting geometry on green fodder yield of Bajra Napier hybrid during first year are furnished in Tables 17a and 17b.

The total green fodder yield of Bajra Napier hybrid over six harvests during first year revealed significantly higher total green fodder yield (72.71 t $ha^{-1}yr^{-1}$) in *Erythrina*. Regarding planting geometry, the highest total green fodder yield of 75.34 t ha^{-1} yr^{-1} was recorded by G_2. With respect to F x G interaction, the highest total green fodder yield of Bajra Napier hybrid was recorded as 79.33 t ha^{-1} yr^{-1} by F_2G_1 and it was on par with F_2G_2 (79.73 t ha^{-1} yr^{-1}).

Regarding the data on individual harvest, among three different top feeds, growing Bajra Napier hybrid as an intercrop in *Erythrina* recorded significantly higher green fodder yield in all the harvests (10.44 t ha^{-1}, 9.66 t ha^{-1}, 12.44 t ha^{-1}, 14.23 t ha^{-1}, 16.64 t ha^{-1} and 9.29 t ha^{-1} respectively). However, the lowest green fodder yield was noticed in drumstick in all the six harvests (9.30 t ha^{-1}, 7.87 t ha^{-1}, 10.62 t ha^{-1}, 12.15 t ha^{-1}, 13.61 t ha^{-1} and 7.54 t ha^{-1} respectively). Among the three planting geometry of top feeds, G_2 recorded significantly the highest green fodder yield in third (13.28 t ha^{-1}), fourth (14.23 t ha^{-1}) and fifth (17.36 t ha^{-1}) harvests. However G_1 recorded the highest green fodder yield in first (10.81 t ha^{-1}), second (9.75 t ha^{-1}) and sixth (9.49 t ha^{-1}) harvests and it was on par with G_2.

Regarding the interaction between top feeds and spacing, significantly higher green fodder yield was noticed in the treatment combination F_2G_1 in first (11.20 t ha^{-1}), second (10.56 t ha^{-1}) and sixth (10.84 t ha^{-1}) harvest. Whereas F_2G_2 recorded significantly higher green fodder yield in third (14.00 t ha^{-1}), fourth (16.12 t ha^{-1}) and fifth (19.06 t ha^{-1}) harvest and at first harvest, it was on par with both F_1G_1 and F_1G_2.

Table 17a. Effect of top feeds and planting geometry on green fodder yield of Bajra Napier hybrid during first year, t ha^{-1}

Treatments	**Green fodder yield**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Total**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	9.36	8.21	11.01	12.74	14.42	7.78	63.53
F_2: *Erythrina* (*Erythrina indica*)	10.44	9.66	12.44	14.23	16.64	9.29	72.71
F_3: Drumstick (*Moringa oleifera*)	9.30	7.87	10.62	12.15	13.61	7.54	61.10
SEm (±)	0.12	0.12	0.09	0.15	0.25	0.09	0.31
CD (P=0.05)	0.496	0.464	0.381	0.609	0.996	0.373	1.239
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	10.81	9.75	12.57	14.36	16.58	9.49	73.56
G_2: 2 m x 0.5 m	10.51	9.56	13.28	15.21	17.36	9.43	75.34
G_3: Paired system	7.79	6.44	8.23	9.56	10.74	5.69	48.44
SEm (±)	0.10	0.09	0.09	0.07	0.13	0.11	0.28
CD (P=0.05)	0.312	0.281	0.283	0.231	0.414	0.346	0.856

Table 17b. Interaction effect of top feeds and planting geometry on green fodder yield of Bajra Napier hybrid during first year, t ha^{-1}

Treatments	**Green fodder yield**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Total**
F X G							
F_1G_1	10.80	9.47	12.21	14.12	16.52	9.10	72.21
$F1G_2$	10.50	9.74	13.45	15.29	17.16	9.47	75.60
F_1G_3	6.79	5.43	7.39	8.83	9.56	4.78	42.77
F_2G_1	11.20	10.56	13.46	15.35	17.92	10.84	79.33
F_2G_2	10.83	9.92	14.00	16.12	19.06	9.80	79.73
F_2G_3	9.30	8.51	9.87	11.24	12.94	7.23	59.07
F_3G_1	10.43	9.23	12.04	13.61	15.28	8.53	69.12
F_3G_2	10.20	9.00	12.39	14.21	15.86	9.03	70.68
F_3G_3	7.29	5.38	7.44	8.63	9.70	5.06	43.49
SEm (±)	0.21	0.20	0.16	0.26	0.43	0.16	0.53
CD (P=0.05)	0.608	0.551	0.541	0.480	0.851	0.645	1.650

4.1.3.5. Dry fodder yield

The data on effect of top feeds and spacing on the dry fodder yield of Bajra Napier hybrid during first year are furnished in Tables 18a and 18b.

The total dry fodder yield of Bajra Napier hybrid was significantly influenced by different top feeds in main plot and significantly higher values were recorded by F_2 (18.11 t ha^{-1} yr^{-1}). Regarding subplot factor, significantly higher total dry fodder yield was noticed in G_2 (18.78 t ha^{-1} yr^{-1}). Moreover, the experiment also showed significant interaction between top feeds and planting geometry with respect to total dry fodder yield. The treatment combination F_2G_2 recorded the highest total dry fodder yield (19.85 t ha^{-1} yr^{-1}) and it was on par with F_2G_1

The data on individual harvests revealed that growing Bajra Napier hybrid as intercrop with *Erythrina* recorded significantly higher dry fodder yield in first (2.574 t ha^{-1}), second (2.42 t ha^{-1}), third (3.33 t ha^{-1}), fourth (3.59 t ha^{-1}), fifth (3.90 t ha^{-1}) and sixth (2.30 t ha^{-1}) harvests. Among the three planting geometry of top feeds, G_2 recorded significantly the highest green fodder yield in the third (3.53 t ha^{-1}), fourth (3.84 t ha^{-1}) and sixth (2.38 t ha^{-1}) harvests. However G_1 recorded higher dry fodder yield in first (2.62 t ha^{-1}), second (2.50 t ha^{-1}) and fifth (3.99 t ha^{-1}) harvests and it was on par with G_2.

The interaction effect of top feeds and spacing showed significant effect on dry fodder yield of top feeds in all the harvests. At first harvest, the treatment combination F_2G_2 recorded the highest dry fodder yield of 2.7 t ha^{-1} and it was on par with F_1G_1, F_2G_1 and F_3G_2. At second harvest, F_1G_2 had showed the highest value (2.75 t ha^{-1}) and it was on par with F_2G_1. In third and fourth harvests, F_2G_2 recorded the highest dry fodder yield (4.03 t ha^{-1} and 4.04 t ha^{-1} respectively) and it was comparable with F_1G_2 and F_2G_1 in fourth harvest. At fifth and sixth harvest F_2G_1 recorded the higher value of 4.29 and 2.81 t ha^{-1} respectively. At fifth harvest, it was on par with F_1G_1, F_1G_2 and F_2G_2.

Table 18a. Effect of top feeds and planting geometry on dry fodder yield of Bajra Napier hybrid during first year, t ha^{-1}.

Treatments	Dry fodder yield						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Total**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	2.34	2.10	2.79	3.24	3.50	1.88	15.85
F_2: *Erythrina* (*Erythrina indica*)	2.57	2.42	3.33	3.59	3.90	2.30	18.11
F_3: Drumstick (*Moringa oleifera*)	2.26	2.09	2.89	2.96	3.14	1.90	15.24
SEm (±)	0.03	0.03	0.03	0.05	0.04	0.03	0.07
CD (P=0.05)	0.108	0.135	0.106	0.198	0.160	0.120	0.276
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	2.62	2.50	3.26	3.67	3.99	2.31	18.36
G_2: 2 m x 0.5 m	2.60	2.47	3.53	3.84	3.97	2.38	18.78
G_3: Paired system	1.96	1.64	2.22	2.28	2.58	1.39	12.06
SEm (±)	0.03	0.02	0.03	0.03	0.07	0.03	0.10
CD (P=0.05)	0.091	0.073	0.090	0.105	0.202	0.082	0.298

Table 18b. Interaction effect of top feeds and planting geometry on dry fodder yield of Bajra Napier hybrid during first year, t ha^{-1}.

Treatments	**Dry fodder yield**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Total**
F X G							
F_1G_1	2.69	2.27	3.05	3.79	4.28	2.00	18.08
$F1G_2$	2.55	2.75	3.35	3.81	3.93	2.45	18.84
F_1G_3	1.78	1.29	1.98	2.11	2.29	1.19	10.64
F_2G_1	2.68	2.63	3.51	3.83	4.29	2.81	19.75
F_2G_2	2.70	2.49	4.03	4.02	4.18	2.44	19.85
F_2G_3	2.35	2.13	2.45	2.91	3.23	1.66	14.72
F_3G_1	2.49	2.59	3.23	3.39	3.41	2.13	17.24
F_3G_2	2.54	2.17	3.21	3.68	3.79	2.25	17.65
F_3G_3	1.75	1.51	2.22	1.81	2.22	1.31	10.81
SEm (±)	0.05	0.06	0.05	0.09	0.07	0.05	0.12
CD (P=0.05)	0.172	0.145	0.170	0.210	0.366	0.158	0.548

4.1.4 Growth and yield attributes of Bajra Napier hybrid during second year

The observations on growth and yield attributes of Bajra Napier hybrid, viz., plant height, leaf stem ratio, number of tillers, tussock diameter, green fodder yield and dry fodder yield during second year and root weight and root volume after two years were recorded and the results are presented below.

4.1.4.1 Plant height

The variation in plant height of Bajra Napier hybrid with respect to the top feeds and planting geometry are furnished in Tables 19a and 19b

The data on mean plant height of all harvests during the second year revealed that average plant height of Bajra Napier hybrid was higher when it was intercropped with *Erythrina* (185.28cm) and it was on par with agathi. .Among subplot treatments, it was observed that the mean plant height was the highest in G_2 (186.05 cm) and it was on par with G_1 (183.86 cm). However the data indicated that the plant height of Bajra Napier hybrid vary significantly with the interaction between top feeds and planting geometry.

Among different top feeds, F_2 recorded the tallest in first (185.15cm), second (167.99 cm), fourth (197.08cm) and sixth (172.15cm) harvests and it was on par with F_1. However, the plant height did not vary significantly in third and fifth harvests.

Regarding the sub plot treatments, G_2 had the tallest plants in first (178.62 cm), second (168.85cm), fourth (201.70 cm) and sixth (178.17 cm) harvests and in all these harvests except sixth harvest, the values were comparable with G_1. However the treatment G_1 recorded the tallest plants in third (186.40 cm) harvest and it was on par with G_2. The data on interaction between top feeds and planting geometry did not show any significant variation with respect to plant height in any of the harvest except sixth harvest. The treatment combination F_2G_2 recorded the tallest plants in sixth harvest (187.09 cm) and it was comparable with F_2G_1 and F_1G_2.

Table 19a: Effect of top feeds and planting geometry on plant height of Bajra Napier hybrid during second year, cm

Treatments	**Plant height**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	170.26	161.23	184.57	196.44	208.03	164.17	180.78
F_2: *Erythrina* (*Erythrina indica*)	185.15	167.99	181.56	197.08	207.77	172.15	185.28
F_3: Drumstick (*Moringa oleifera*)	165.55	154.97	173.71	185.01	200.38	159.11	173.12
SEm (±)	3.76	1.73	2.39	1.67	3.00	1.60	1.73
CD (P=0.05)	15.141	6.982	NS	6.716	NS	6.458	6.991
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	177.53	168.32	186.40	196.29	205.13	169.49	183.86
G_2: 2 m x 0.5 m	178.62	168.85	184.67	201.71	204.29	178.17	186.05
G_3: Paired system	164.81	147.03	168.76	180.53	206.76	147.77	169.28
SEm (±)	2.66	2.81	3.35	3.14	2.63	2.32	1.14
CD (P=0.05)	8.297	8.758	10.447	9.774	NS	7.241	3.560

NS: Not Significant

Table 19b. Interaction effect of top feeds and planting geometry on plant height of Bajra Napier hybrid during second year, cm

Treatments	**Plant height**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	174.94	168.65	193.94	198.81	205.55	162.08	184.00
F1G_2	177.91	166.85	181.96	214.80	201.89	174.41	186.30
F_1G_3	157.93	148.20	177.81	175.71	216.66	156.01	172.05
F_2G_1	190.38	178.28	184.66	205.49	207.72	184.72	191.88
F_2G_2	189.02	179.88	191.03	196.62	210.51	187.09	192.36
F_2G_3	176.05	145.80	169.00	189.14	205.06	144.64	171.62
F_3G_1	167.27	158.02	180.62	184.57	202.12	161.67	175.71
F_3G_2	168.93	159.82	181.02	193.70	200.48	173.00	179.49
F_3G_3	160.45	147.08	159.48	176.75	198.56	142.67	164.16
SEm (±)	6.51	3.00	4.13	2.89	5.19	2.77	3.00
CD (P=0.05)	NS	NS	NS	NS	NS	13.250	NS

NS: Not Significant

4.1.4.2. Leaf stem ratio

The results on the effect of top feeds and its planting geometry on leaf stem ratio of Bajra Napier hybrid during second year were analyzed and the results are furnished in Tables 20a and 20b.

Among the three different top feeds, intercropping Bajra Napier hybrid with *Erythrina* (F_2) recorded significantly higher mean leaf stem ratio of 2.16 during second year. Planting geometry of top feeds had significant effect on leaf stem ratio of Bajra Napier hybrid and mean leaf stem ratio was found to be significantly higher for both G_1 and G_2 (2.12). Among treatment combinations, higher average leaf stem ratio was noticed for F_2G_2 (2.32) and it was comparable to F_1G_1 and F_2G_1.

With respect to the variation in leaf stem ratio with respect to different cropping systems, intercropping *Erythrina* with Bajra Napier hybrid recorded significantly higher value in first harvest (2.12). The same treatment also recorded the highest value in second (1.91), third (1.93) and sixth harvests (1.87) and it was comparable with the leaf stem ratio of Bajra Napier hybrid intercropping with agathi (F_1) in all these three harvests.

Planting geometry of top feed had significant effect on leaf stem ratio of Bajra Napier hybrid and among the individual harvests, higher value was noticed by G_2 in first (2.0), second (1.94), third (1.86) and fifth (2.95) harvests. However in fourth and sixth harvests, higher leaf stem ratio was noticed in G_1 (2.49and 1.88 respectively). Growing top feeds under paired row system (G_3) recorded the lowest leaf stem ration in all the six harvests.

The results also revealed significant interaction between top feeds and planting geometry in all the harvests, except first and fourth harvest. At second and third harvests, F_2G_2 recorded higher leaf stem ratio (2.08 and 2.11) and it was on par with F_2G_1, F_1G_2 and F_1G_1 in both the harvests. The treatment combination, F_2G_2 had higher value in fifth harvest (3.21) and F_2G_1 in sixth harvest (2.23).

Table 20a: Effect of top feeds and planting geometry on leaf stem ratio of Bajra Napier hybrid during second year

Treatments	**Leaf stem ratio**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	1.73	1.82	1.88	2.27	2.54	1.78	2.00
F_2: *Erythrina* (*Erythrina indica*)	2.12	1.91	1.93	2.28	2.83	1.87	2.16
F_3: Drumstick (*Moringa oleifera*)	1.65	1.50	1.53	2.30	2.59	1.19	1.79
SEm (±)	0.09	0.03	0.03	0.03	0.09	0.03	0.01
CD (P=0.05)	0.376	0.130	0.127	NS	NS	0.129	0.044
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	1.87	1.80	1.85	2.49	2.83	1.88	2.12
G_2: 2 m x 0.5 m	2.00	1.94	1.86	2.43	2.95	1.53	2.12
G_3: Paired system	1.62	1.49	1.63	1.94	2.19	1.43	1.72
SEm (±)	0.07	0.04	0.04	0.06	0.05	0.04	0.02
CD (P=0.05)	0.223	0.117	0.124	0.170	0.144	0.134	0.070

Table 20b. Interaction effect of top feeds and planting geometry on leaf stem ratio of Bajra Napier hybrid during second year

Treatments	**Leaf stem ratio**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	1.93	2.00	2.02	2.60	2.88	2.14	2.26
$F1G_2$	1.77	2.07	1.84	2.28	2.77	1.71	2.07
F_1G_3	1.49	1.41	1.77	1.94	1.97	1.51	1.68
F_2G_1	2.16	1.99	2.07	2.37	3.06	2.23	2.31
F_2G_2	2.29	2.08	2.11	2.45	3.21	1.76	2.32
F_2G_3	1.91	1.65	1.63	2.00	2.21	1.63	1.84
F_3G_1	1.53	1.40	1.48	2.50	2.54	1.28	1.79
F_3G_2	1.95	1.68	1.65	2.55	2.86	1.13	1.97
F_3G_3	1.47	1.40	1.48	1.86	2.39	1.17	1.63
SEm (±)	0.16	0.06	0.05	0.06	0.16	0.06	0.02
CD (P=0.05)	NS	0.219	0.230	NS	0.297	0.248	0.125

NS: Not Significant

4.1.4.3. Number of tillers per hill

The data representing the effect of different top feeds and planting geometry on number of tillers of Bajra Napier hybrid during second year are furnished in Tables 21a and 21b.

The data showed that among different top feeds, the highest mean tillers count (25.55) was observed in F_2. Among planting geometry in subplot, significantly the highest average number of tillers were noticed in G_2 (24.94).The F x G interaction was significant with respect to mean number of tillers and treatment combination F_2G_2 recorded significantly higher mean number of tiller (30.70).

Regarding individual harvests, no significant interaction with respect to number of tillers of Bajra Napier hybrid was noticed in all the harvests, except third and fourth. F_2 (Bajra Napier hybrid + *Erythrina*) recorded the highest number of tillers in these two harvests (28.30 and 24.87 respectively). However in fourth harvest, the value of F_2 was comparable with F_1 (21.37).

Among sub plot treatments, significant variation in number of tillers were observed in all the harvests, except sixth with the highest value in G_2 (27.63, 22.15, 27.13, 23.41 and 30 respectively). The data on interaction between top feeds and planting on number of tillers showed that it significantly varied in all the harvests except third and sixth harvest. The treatment combination F_2G_2 recorded the highest number of tillers in first (33.11), second (26.39), fourth (29.82) and fifth (37.560) harvest. At second harvest, the value was on par with F_1G_2, F_1G_3, F_2G_1 and F_3G_1.However in fourth and fifth harvest, the values were comparable with F_2G_1.

4.1.4.4. Tussock diameter

Tables 22a and 22b present the data on the effect of top feeds and planting geometry on tussock diameter of Bajra Napier hybrid during second year.

The results on mean tussock diameter of all the six harvests during the second year revealed that the treatment F_2 noticed significantly higher mean tussock diameter (70.78 cm). Among three different spacing of top feeds, average tussock diameter of Bajra Napier hybrid was higher for G_2 (70.57cm) and it was on par with G_1. However the effect of interaction between top feeds and planting geometry was not significant The results showed that tussock diameter of Bajra Napier hybrid varied significantly to different top feeds in third, fourth and fifth harvests and the highest value was noticed in F_2 in all these three harvests (66.31 cm, 68.09 cm and 89.00 cm respectively). At third and fourth harvests, the values were on par with F_1.Among three planting geometry, the highest tussock diameter was noticed in G_2 for all the harvests (64.56 cm, 66.91cm, 88.385 cm and 67.82 cm respectively) and it was on par with G_1. However G_1 recorded the highest value (69.16cm) at first harvest and it was on par with G_2.

No significant interaction was observed between top feeds and spacing with respect to tussock diameter in any of the harvests

Table 21a. Effect of top feeds and planting geometry on number of tillers per hill of Bajra Napier hybrid during second year

Treatments	**Number of tillers per hill**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	25.17	19.55	23.27	21.37	23.80	17.54	21.78
F_2: *Erythrina* (*Erythrina indica*)	25.63	22.35	28.30	24.87	30.89	21.25	25.55
F_3: Drumstick (*Moringa oleifera*)	22.29	20.59	19.08	17.55	22.05	18.06	19.94
SEm (±)	2.38	0.81	1.01	1.11	2.03	1.94	0.48
CD (P=0.05)	NS	NS	4.054	4.491	NS	NS	1.932
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	22.28	21.71	23.70	20.71	27.48	19.96	22.64
G_2: 2 m x 0.5 m	27.63	22.15	27.13	23.41	30.00	19.35	24.95
G_3: Paired system	23.18	18.64	19.82	19.67	19.26	17.54	19.68
SEm (±)	0.84	0.93	1.17	0.81	1.16	1.04	0.30
CD (P=0.05)	2.606	2.898	3.656	2.509	3.597	NS	0.946

NS: Not Significant

Table 21b: Interaction effect of top feeds and planting geometry on number of tillers per hill of Bajra Napier hybrid during second year

Treatments	**Number of tillers per hill**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	23.39	16.58	21.22	18.31	23.17	16.31	19.83
$F1G_2$	25.73	21.07	27.73	23.54	26.41	18.15	23.77
F_1G_3	26.40	21.01	20.87	22.25	21.81	18.18	21.75
F_2G_1	24.74	25.68	26.55	27.48	36.51	21.43	27.06
F_2G_2	33.11	26.39	34.05	29.82	37.56	23.25	30.70
F_2G_3	19.06	14.99	24.29	17.32	18.59	19.06	18.89
F_3G_1	18.72	22.87	23.33	16.34	22.74	22.16	21.03
F_3G_2	24.07	18.98	19.61	16.87	26.03	16.65	20.37
F_3G_3	24.07	19.93	14.29	19.44	17.38	15.38	18.41
SEm (±)	4.12	1.41	1.74	1.93	3.51	3.36	0.83
CD (P=0.05)	5.578	5.426	NS	4.971	7.342	NS	1.906

NS: Not Significant

Table 22a. Effect of top feeds and planting geometry on tussock diameter of Bajra Napier hybrid during second year, cm

Treatments	Tussock diameter						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	65.40	61.27	61.44	63.73	77.79	65.17	65.80
F_2: *Erythrina* (*Erythrina indica*)	69.50	64.93	66.31	68.09	89.00	66.82	70.78
F_3: Drumstick (*Moringa oleifera*)	63.23	57.84	58.13	58.90	73.00	62.07	62.19
SEm (±)	2.09	1.72	1.43	1.72	1.54	1.66	0.53
CD (P=0.05)	NS	NS	5.776	6.933	6.194	NS	2.138
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	69.16	63.43	62.84	64.68	84.83	66.64	68.60
G_2: 2 m x 0.5 m	67.45	64.56	66.31	68.91	88.39	67.82	70.57
G_3: Paired system	61.51	56.06	56.73	57.13	66.57	59.60	59.60
SEm (±)	1.60	1.48	1.33	1.33	1.66	1.26	0.76
CD (P=0.05)	4.995	4.620	4.147	4.140	5.164	3.933	2.363

NS: Not Significant

Table 22b. Interaction effect of top feeds and planting geometry on tussock diameter of Bajra Napier hybrid during second year, cm

Treatments	**Tussock Diameter**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Mean**
F X G							
F_1G_1	68.49	62.70	63.10	64.57	84.43	66.97	68.38
$F1G_2$	67.45	63.40	64.66	67.73	85.48	68.83	69.59
F_1G_3	60.25	57.72	56.55	58.91	63.47	59.72	59.44
F_2G_1	70.53	67.26	68.27	71.03	92.13	69.23	73.08
F_2G_2	70.17	69.13	71.80	75.11	98.90	69.15	75.71
F_2G_3	67.79	58.41	58.86	58.13	75.97	62.07	63.54
F_3G_1	68.47	60.32	57.15	58.45	77.93	63.70	64.34
F_3G_2	64.71	61.14	62.48	63.89	80.78	65.48	66.41
F_3G_3	56.49	52.07	54.77	54.37	60.28	57.01	55.83
SEm (±)	3.61	2.98	2.48	2.98	2.66	2.88	0.92
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

NS: Not Significant.

4.1.4.5. Green fodder yield

The results of effect of different top feeds and planting geometry on green fodder yield of Bajra Napier hybrid during second year are presented in Tables 23a and 23b.

The total green fodder yield of Bajra Napier hybrid over six harvest during second year revealed significantly higher total green fodder yield of 73.54 t $ha^{-1}yr^{-1}$ with *Erythrina*. Among planting geometry, significantly higher total green fodder yield of 75.98 t ha^{-1} yr^{-1} was recorded by G_2. Regarding the interaction between top feeds and planting geometry, the highest total green fodder yield of Bajra Napier hybrid was recorded by F_2G_2 (80.68 t ha^{-1} yr^{-1}) and it was on par with F_2G_2 (80.33t ha^{-1} yr^{-1}).

Regarding individual harvest data,the results were similar to first year in which F_2 significantly higher green fodder yield in all the six harvests (10.16 t ha^{-1}, 9.27 t ha^{-1},12.85 t ha^{-1},14.57 t ha^{-1},17.03 t ha^{-1} and 9.65 t ha^{-1} respectively) .Moreover, F_3 recorded the lowest value in all harvests (8.38 t ha^{-1},7.91 t ha^{-1},10.72 t ha^{-1},12.45,13.58 t ha^{-1} and 8.31 t ha^{-1} respectively).

Regarding the sub plot treatments, G_2 recorded the highest green fodder yield in first (10.51 t ha^{-1}), second (9.64 t ha^{-1}), third (13.30 t ha^{-1}), fourth (15.11 t ha^{-1}) and sixth (10.50 t ha^{-1}) harvests. Whereas, G_1 recorded significantly higher value in fifth harvest (17.28 t ha^{-1}). At second harvest, the G_2 was comparable with G_1.

Regarding the interaction between top feeds and spacing, significantly higher green fodder yield was noticed in the treatment combination F_2G_2 in first (11.53 t ha^{-1}), second (10.21 t ha^{-1}), third (14.18 t ha^{-1}) and fourth harvest (16.01 t ha^{-1}). Whereas, F_2G_1 recorded significantly higher green fodder yield in fifth harvest (19.80 t ha^{-1}). In harvest three and four, the highest value of green fodder yield was comparable to F_2G_1.

4.1.4.6. Dry fodder yield

Tables 24 a and 24 b present the variation in dry fodder yield of Bajra Napier hybrid with respect to top feeds and planting geometry during second year.

The total dry fodder yield of Bajra Napier hybrid was significantly influenced by different top feeds in main plot and significantly higher value was recorded by F_2 (19.16 t ha^{-1} yr^{-1}).Regarding subplot factor, significantly higher total dry fodder yield was noticed by G_2 (19.70 t ha^{-1} yr^{-1}). Moreover, the total dry fodder yield was also influenced by the FxG interaction and the highest value was noticed in F_2G_2 (21.11 t ha^{-1} yr^{-1}) and it was on par with F_2G_1.

Regarding the main plot treatments with different top feeds, significantly higher green fodder yield was noticed in F_2 for all the six harvests (2.63 t ha^{-1}, 2.43 t ha^{-1}, 3.33 t ha^{-1},3.81 t ha^{-1},4.43 t ha^{-1} and 2.53 t ha^{-1} respectively) and a total dry fodder yield of 19.16 t ha^{-1} yr^{-1}. As in the first year the lowest dry fodder yield was observed in drumstick in all the harvests.

Among three planting geometry of top feeds, G_2 recorded significantly the highest dry fodder yield in second (2.51 t ha^{-1}) third (3.53 t ha^{-1}) fourth (3.87 t ha^{-1}) and sixth harvest (2.73 t ha^{-1}). However G_1 recorded higher dry fodder yield in first (2.71 t ha^{-1}) and fifth (4.66 t ha^{-1}) harvests and at first harvest, G_1 was on par with G_2. However in second and third harvests, the value were comparable with G_1.

The treatment combinations did not show any significant effect on dry fodder yield of Bajra Napier hybrid in any of the harvests, except first and sixth harvests. At first harvest, F_2G_2 recorded the highest dry fodder yield of 2.93 t ha^{-1} and it was on par with F_1G_1, F_1G_2 and F_2G_2 .However, at sixth harvest, F1G_2 had higher dry fodder yield (2.81 t ha^{-1}) and it was on par with F_2G_1 and F_2G_2.

Table 23 a. Effect of top feeds and planting geometry on green fodder yield of Bajra Napier hybrid during second year, t ha^{-1}

Treatments	Green fodder yield						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Total**
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	9.11	8.13	11.30	12.83	14.46	8.96	64.78
F_2: *Erythrina* (*Erythrina indica*)	10.16	9.27	12.85	14.57	17.03	9.65	73.54
F_3: Drumstick (*Moringa oleifera*)	8.38	7.91	10.72	12.45	13.58	8.31	61.34
SEm (±)	0.06	0.07	0.08	0.08	0.09	0.15	0.23
CD (P=0.05)	0.243	0.292	0.315	0.334	0.371	0.593	0.914
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	10.17	9.34	12.84	14.67	17.28	9.84	74.14
G_2: 2 m x 0.5 m	10.51	9.64	13.30	15.11	16.91	10.50	75.98
G_3: Paired system	6.97	6.32	8.72	10.07	10.88	6.58	49.54
SEm (±)	0.10	0.11	0.08	0.11	0.11	0.09	0.15
CD (P=0.05)	0.299	0.344	0.251	0.346	0.338	0.266	0.477

Table 23b. Interaction effect of top feeds and planting geometry on green fodder yield of Bajra Napier hybrid during second year, t ha^{-1}

Treatments	**Green fodder yield**						
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**	**Harvest V**	**Harvest VI**	**Total**
F X G							
F_1G_1	10.30	9.08	12.53	14.25	16.57	9.96	72.68
F1G_2	10.49	9.44	13.36	14.90	16.89	11.06	76.13
F_1G_3	6.54	5.86	8.02	9.34	9.92	5.87	45.53
F_2G_1	10.67	9.94	13.87	15.70	19.80	10.36	80.33
F_2G_2	11.53	10.21	14.18	16.01	18.06	10.69	80.68
F_2G_3	8.29	7.67	10.50	12.00	13.25	7.90	59.60
F_3G_1	9.54	9.00	12.13	14.06	15.47	9.20	69.41
F_3G_2	9.51	9.27	12.37	14.41	15.79	9.77	71.13
F_3G_3	6.07	5.45	7.64	8.87	9.48	5.97	43.48
SEm (±)	0.11	0.13	0.14	0.14	0.16	0.16	0.39
CD (P=0.05)	0.543	0.626	0.475	0.638	0.631	0.631	0.953

Table 24a. Effect of top feeds and planting geometry on dry fodder yield of Bajra Napier hybrid during second year, t ha^{-1}

Treatments	Dry fodder yield						
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI	Total
Top feeds (F)							
F_1: Agathi (*Sesbania grandiflora*)	2.41	2.08	3.00	3.15	3.84	2.27	16.75
F_2: *Erythrina* (*Erythrina indica*)	2.63	2.43	3.33	3.81	4.43	2.53	19.16
F_3: Drumstick (*Moringa oleifera*)	2.16	2.04	2.85	3.25	3.64	2.15	16.09
SEm (±)	0.02	0.04	0.02	0.05	0.04	0.04	0.06
CD (P=0.05)	0.069	0.169	0.093	0.199	0.142	0.175	0.233
Planting geometry of top feeds (G)							
G_1: 2 m x 1 m	2.71	2.42	3.39	3.70	4.66	2.55	19.43
G_2: 2 m x 0.5 m	2.69	2.51	3.53	3.87	4.38	2.73	19.70
G_3: Paired system	1.80	1.62	2.27	2.63	2.87	1.67	12.87
SEm (±)	0.03	0.03	0.05	0.05	0.06	0.03	0.08
CD (P=0.05)	0.103	0.102	0.156	0.144	0.172	0.099	0.247

Table 24b. Interaction effect of top feeds and plan geometry o dry fodder yield of Bajra Napier hybrid during second year, t ha^{-1}

Treatments	Dry fodder yield						
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI	Total
F X G							
F_1G_1	2.88	2.31	3.27	3.35	4.58	2.53	18.93
F1G_2	2.70	2.43	3.58	3.67	4.31	2.81	19.50
F_1G_3	1.66	1.50	2.15	2.42	2.64	1.45	11.81
F_2G_1	2.79	2.61	3.57	4.12	5.12	2.74	20.94
F_2G_2	2.93	1.98	3.76	4.20	4.73	2.79	21.11
F_2G_3	2.16	2.70	2.67	3.11	3.44	2.06	15.42
F_3G_1	2.45	2.36	3.34	3.64	4.27	2.37	18.42
F_3G_2	2.45	2.39	3.24	3.73	4.10	2.58	18.49
F_3G_3	1.58	1.38	1.97	2.38	2.55	1.51	11.36
SEm (±)	0.03	0.07	0.04	0.09	0.06	0.08	0.10
CD (P=0.05)	0.185	NS	NS	NS	NS	0.196	0.455

NS: Not Significant

4.1.4.7. Root weight and root volume of Bajra Napier hybrid

The result on effect top feeds and spacing on root weight and root volume of Bajra Napier hybrid after two years are presented in Table 25.

Among the three top feeds, F_2 significantly the highest root fresh weight (467.95 g per plant).Whereas both root dry weight and root volume did not vary significantly with respect to different top feeds.

Regarding the subplot factor, growing top feeds at planting geometry of 2 m x 1 m (G_1) had significantly higher root fresh weight (460.36 g per plant) and root dry weight (61.87 g per plant) and it was on par with top feeds in paired system (G_3). However, the root volume did not vary significantly.

The interaction effect of top feeds and planting geometry exhibited a considerable variation with respect to root weight and root volume. The treatment combination F_2G_1 recorded the highest root fresh weight, dry weight and root volume (540.41 g per plant, 67.97 g per plant and 695.40 cm^3 per plant respectively).The values were on par with F_1G_2, F_2G_2 and F_3G_1.

Table 25. Effect of top feeds, planting geometry and F x G interaction on root weight and root volume of Bajra Napier hybrid after two years

Treatments	**Root weight (g per plant)**		**Root volume (cm^3 g per plant)**
	Fresh weight	**Dry weight**	
Top feeds (F)			
F_1: Agathi (*Sesbania grandiflora*)	427.90	55.20	525.88
F_2: *Erythrina* (*Erythrina indica*)	467.95	58.91	580.39
F_3: Drumstick (*Moringa oleifera*)	428.14	53.97	521.66
SEm (±)	27.60	1.46	14.17
CD (P=0.05)	6.845	NS	NS
Planting geometry (G)			
G_1: 2 m x 1 m	460.36	61.87	560.68
G_2: 2 m x 0.5 m	405.72	46.67	572.74
G_3: Paired system	457.91	59.54	494.50
SEm (±)	15.45	2.08	27.53
CD (P=0.05)	48.136	6.485	NS
Interaction effect			
F_1G_1	410.29	52.51	503.73
F_1G_2	493.05	70.38	619.37
F_1G_3	380.36	42.72	454.53
F_2G_1	540.41	67.97	695.40
F_2G_2	477.06	62.08	604.17
F_2G_3	386.36	46.75	441.61
F_3G_1	493.71	64.11	574.13
F_3G_2	340.27	47.25	403.47
F_3G_3	450.43	50.56	587.37
SEm (±)	11.86	2.53	24.54
CD (P=0.05)	85.565	11.886	153.685

4.1.5 Pooled analysis

Pooled analysis of two years data of both green fodder yield and dry fodder yield of top feeds are presented in Tables 26a, 26b and 26c.

The pooled data of top feeds revealed that among different cropping systems, C_2 recorded significantly higher total green fodder yield (18.60 t ha^{-1}) and dry fodder yield (4.76 t ha^{-1}). Among different top feeds, agathi was significantly superior with respect to green fodder yield (21.97 t ha^{-1}) and dry fodder yield (5.57 t ha^{-1}). Among planting geometry, G_3 recorded higher green fodder yield of 16.62 t ha^{-1} and dry fodder yield of 4.24 t ha^{-1} and both were on par with G_2. The C x F interaction significantly varied with total green fodder yield and dry fodder yield and higher values were noticed in C_2F_1 (25.79 t ha^{-1} yr^{-1} and 6.59 t ha^{-1} respectively). Moreover C_2G_2 recorded highest green fodder yield (19.77 t ha^{-1} yr^{-1}) and dry fodder yield (5.04 t ha^{-1} yr^{-1}).The interaction between top feeds and planting geometry significantly varied and higher value had noticed in F_1G_2 with respect to total green fodder yield (24.41 t ha^{-1} yr^{-1}) and total dry fodder yield (6.14 t ha^{-1} yr^{-1}). Moreover C x F x G interaction significantly varied with yield and $C_2F_1G_2$ recorded significantly higher green fodder yield (30.92 t ha^{-1} yr^{-1}) and dry fodder yield (7.83 t ha^{-1} yr^{-1}).

Pooled analysis of two year data of Bajra Napier hybrid are presented in Table 27. Result of the study revealed that among top feeds both green fodder yield and dry fodder yield were significantly more in F_2 (73.12 t ha^{-1} yr^{-1} and 18.63 t ha^{-1} yr^{-1} respectively). However among planting geometry G_2 recorded higher value with respect to total green fodder yield (75.66 t ha^{-1} yr^{-1}) and dry fodder yield (19.24 t ha^{-1} yr^{-1}). Significant interaction between top feeds and planting geometry was noticed with respect to total yield and higher value noticed in F_2G_2 (80.20 t ha^{-1} yr^{-1} and 20.48 t ha^{-1} yr^{-1} respectively) and it was on par with F_2G_1.

Table 26 a. Effect of cropping system, top feeds and planting geometry on green fodder yield and dry fodder yield of top feeds (Pooled mean of 2 years), t ha^{-1} yr^{-1}

Treatments	Total green fodder yield	Total dry fodder yield
Cropping system (C)		
C_1: Sole crop (Top feeds)	13.53	3.43
C_2 :Intercrop (Bajra Napier Hybrid)	18.60	4.76
SEm (±)	0.07	0.01
CD (P=0.05)	0.431	0.080
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	21.97	5.57
F_2: *Erythrina* (*Erythrina indica*)	10.23	2.60
F_3: Drumstick (*Moringa oleifera*)	15.99	4.11
SEm (±)	0.09	0.03
CD (P=0.05)	0.285	0.081
Planting geometry of top feed (G)		
G_1: 2 m x 1 m	15.06	3.85
G_2: 2 m x 0.5 m	16.52	4.19
G_3: Paired system	16.62	4.24
SEm (±)	0.10	0.03
CD (P=0.05)	0.285	0.073

Table 26b. Effect of C x F, C x G and F x G interactions on green fodder yield and dry fodder yield of top feeds (Pooled data of 2 years), t ha^{-1} yr^{-1}

Treatments	Total green fodder yield	Total dry fodder yield
C_1F_1	18.15	4.56
C_1F_2	10.94	2.75
C_1F_3	11.49	2.98
C_2F_1	25.79	6.59
C_2F_2	9.52	2.46
C_2F_3	20.49	5.24
SEm (±)	0.12	0.04
CD (P=0.05)	0.403	0.115
C_1G_1	12.89	3.28
C_1G_2	13.27	3.35
C_1G_3	14.42	3.66
C_2G_1	17.22	4.42
C_2G_2	19.77	5.04
C_2G_3	18.82	4.82
SEm (±)	0.14	0.04
CD (P=0.05)	0.404	0.103
F_1G_1	19.52	4.93
F_1G_2	24.41	6.14
F_1G_3	21.99	5.66
F_2G_1	9.95	2.54
F_2G_2	10.08	2.55
F_2G_3	10.64	2.71
F_3G_1	15.69	4.09
F_3G_2	15.05	3.89
F_3G_3	17.23	4.36
SEm (±)	0.17	0.04
CD (P=0.05)	0.494	0.126

Table 26c. Interaction effect of cropping system, top feeds and planting geometry on green fodder yield and dry fodder yield of top feeds (Pooled data of 2 years), t ha^{-1} yr^{-1}

Treatments	Total green fodder yield	Total dry fodder yield
$C_1F_1G_1$	17.03	4.28
$C_1F_1G_2$	17.89	4.44
$C_1F_1G_3$	19.53	4.96
$C_1F_2G_1$	10.29	2.59
$C_1F_2G_2$	11.04	2.75
$C_1F_2G_3$	11.50	2.91
$C_1F_3G_1$	11.36	2.96
$C_1F_3G_2$	10.89	2.85
$C_1F_3G_3$	12.22	3.13
$C_2F_1G_1$	22.02	5.57
$C_2F_1G_2$	30.92	7.83
$C_2F_1G_3$	24.44	6.36
$C_2F_2G_1$	9.62	2.50
$C_2F_2G_2$	9.16	2.35
$C_2F_2G_3$	9.77	2.52
$C_2F_3G_1$	20.02	5.21
$C_2F_3G_2$	19.22	4.94
$C_2F_3G_3$	22.23	5.58
SEm (±)	0.24	0.06
CD (P=0.05)	0.699	0.178

Table 27: Effect of top feeds and planting geometry and F x G interaction on total green fodder yield, dry fodder yield of Bajra Napier hybrid (Pooled mean of two years), t ha^{-1} yr^{-1}

Treatments	**Total green fodder yield**	**Total dry fodder yield**
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	64.16	16.30
F_2: *Erythrina* (*Erythrina indica*)	73.12	18.63
F_3: Drumstick (*Moringa oleifera*)	61.22	15.66
SEm (±)	0.27	0.03
CD (P=0.05)	1.071	0.120
Planting geometry of top feed (G)		
G_1: 2m x 1m	73.85	18.89
G_2: 2m x 0.5m	75.66	19.24
G_3: Paired system	48.99	12.46
SEm (±)	0.16	0.07
CD (P=0.05)	0.513	0.218
F X G		
F_1G_1	72.45	18.50
F1G_2	75.87	19.17
F_1G_3	44.15	11.23
F_2G_1	79.83	20.34
F_2G_2	80.20	20.48
F_2G_3	59.34	15.07
F_3G_1	69.27	17.83
F_3G_2	70.91	18.07
F_3G_3	43.48	11.09
SEm (±)	0.46	0.05
CD (P=0.05)	1.037	0.386

4.1.6 Physiological parameter

4.1.6.1 Chlorophyll content of top feeds

Tables 28a, 28b and 28c shows the effect of cropping system, top feeds and spacing on total chlorophyll content of top feeds in first year and second year.

The results revealed that both cropping system and planting geometry did not have significant effect on total chlorophyll content of top feeds, However significant variation recorded with different top feeds. Among three different top feeds, significantly higher total chlorophyll content was noticed in agathi in both first year (2.19 mg g^{-1}) and second year (2.17 mg g^{-1}).

The interaction effect of cropping system with top feeds varied significantly in both the years and higher value was noticed in C_1F_1 (2.32 and 2.20 mg g^{-1}respectively). However in the second year the value was statistically on par with C_2F_1 (2.14 mg g^{-1}).The interaction effect of cropping system with spacing (CG) varied significantly in first year, however it was non-significant in second year. The treatment combination C_1G_2 recorded higher total chlorophyll content (1.65 mg g^{-1}) in first year and it was statistically on par with C_1G_1 (1.543 mg g^{-1}) and C_2G_1 (1.62 mg g^{-1}). Moreover, C_2G_2 recorded the lowest chlorophyll content (1.47 mg g^{-1}). The interaction effect of top feeds with planting geometry did not vary significantly in both the years.

Significant interaction between cropping system, top feeds and planting geometry was noticed with respect to total chlorophyll content with second year. However it was not significant in the first year. The treatment combination, $C_1F_2G_2$ recorded the highest total chlorophyll content in second year and it was comparable with $C_1F_1G_1$, $C_1F_1G_2$, $C_1F_1G_3$ and $C_2F_1G_1$.

Table 28a. Effect of cropping system, top feeds and planting geometry on total chlorophyll content of top feeds, mg g^{-1}

Treatments	Total chlorophyll content	
	First year	**Second year**
Cropping system (C)		
C_1: Sole crop (Top feeds)	1.56	1.50
C_2 :Intercrop (Bajra Napier Hybrid)	1.53	1.50
SEm (±)	0.01	0.03
CD (P=0.05)	NS	NS
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	2.19	2.17
F_2: *Erythrina* (*Erythrina indica*)	1.99	1.89
F_3: Drumstick (*Moringa oleifera*)	0.44	0.43
SEm (±)	0.03	0.03
CD (P=0.05)	0.084	0.089
Planting geometry (G)		
G_1: 2 m x 1 m	1.58	1.47
G_2: 2 m x 0.5 m	1.56	1.55
G_3: Paired system	1.49	1.47
SEm (±)	0.03	0.03
CD (P=0.05)	NS	NS

NS: Not Significant

Table 28b. Effect of C x F, C x G and F x G interactions on total chlorophyll content of top feeds, mg g^{-1}

Treatments	**Total chlorophyll content**	
	First year	**Second year**
C_1F_1	2.32	2.20
C_1F_2	1.88	1.97
C_1F_3	0.48	0.31
C_2F_1	2.07	2.14
C_2F_2	2.11	1.81
C_2F_3	0.41	0.54
SEm (±)	0.04	0.04
CD (P=0.05)	0.118	0.126
C_1G_1	1.54	1.45
C_1G_2	1.65	1.58
C_1G_3	1.49	1.45
C_2G_1	1.62	1.49
C_2G_2	1.47	1.52
C_2G_3	1.49	1.49
SEm (±)	0.04	0.04
CD (P=0.05)	0.114	NS
F_1G_1	2.27	2.21
F_1G_2	2.22	2.24
F_1G_3	2.09	2.07
F_2G_1	1.99	1.79
F_2G_2	2.03	1.93
F_2G_3	1.96	1.96
F_3G_1	0.48	0.42
F_3G_2	0.43	0.47
F_3G_3	0.43	0.39
SEm (±)	0.05	0.05
CD (P=0.05)	NS	NS

NS: Not Significant

Table 28c. Effect of cropping system, top feeds and planting geometry on total chlorophyll content of top feeds, mg g^{-1}

Treatments	**Total chlorophyll content**	
	First year	**Second year**
$C_1F_1G_1$	2.31	2.22
$C_1F_1G_2$	2.40	2.20
$C_1F_1G_3$	2.25	2.18
$C_1F_2G_1$	1.76	1.80
$C_1F_2G_2$	2.04	2.29
$C_1F_2G_3$	1.84	1.83
$C_1F_3G_1$	0.56	0.33
$C_1F_3G_2$	0.49	0.25
$C_1F_3G_3$	0.39	0.35
$C_2F_1G_1$	2.23	2.19
$C_2F_1G_2$	2.04	2.27
$C_2F_1G_3$	1.93	1.96
$C_2F_2G_1$	2.23	1.77
$C_2F_2G_2$	2.02	1.58
$C_2F_2G_3$	2.07	2.09
$C_2F_3G_1$	0.40	0.50
$C_2F_3G_2$	0.36	0.70
$C_2F_3G_3$	0.46	0.43
SEm (±)	0.07	0.07
CD (P=0.05)	NS	0.194

NS: Not Significant

4.1.6.2 Chlorophyll content of Bajra Napier hybrid

The total chlorophyll content of Bajra Napier hybrid as influenced by top feeds and planting geometry is presented in Table 29.

Among three different top feeds, the highest total chlorophyll content recorded when Bajra Napier hybrid was intercropped with agathi (1.11 mg g^{-1}) in first year and it was on par with which intercropped with *Erythrina*. However the total chlorophyll content was not significant in the second year.

Regarding planting geometry, no significant variation in total chlorophyll content was observed in first year; however significant variation was noticed during the second year. Top feeds at 2 m x 0.5 m geometry (G_2) recorded significantly the highest total chlorophyll content in the second year (1.06 mg g^{-1})

Significant interaction between top feeds and planting geometry with respect to total chlorophyll content was observed in second year, whereas it was non-significant during the first year. The treatment combination F_1G_2 showed highest total chlorophyll content of 1.12 mg g^{-1} and it was on par with F_1G_3, F_2G_3 and F_3G_1.

Table 29. Effect of top feeds, planting geometry and F x G interaction total chlorophyll content of Bajra Napier hybrid, mg g^{-1}

Treatments	Total chlorophyll content	
	First year	Second year
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	1.11	1.05
F_2: *Erythrina* (*Erythrina indica*)	1.07	0.99
F_3: Drumstick (*Moringa oleifera*)	0.92	0.97
SEm (±)	0.03	0.03
CD (P=0.05)	0.118	NS
Planting geometry (G)		
G_1: 2 m x 1 m	1.05	0.99
G_2: 2 m x 0.5 m	1.08	1.06
G_3: Paired system	0.96	0.95
SEm (±)	0.03	0.02
CD (P=0.05)	NS	0.067
Interaction (FxG)		
F_1G_1	0.95	0.98
$F1G_2$	0.88	1.12
F_1G_3	0.94	1.03
F_2G_1	1.07	0.95
F_2G_2	1.14	0.91
F_2G_3	0.99	1.11
F_3G_1	1.13	1.04
F_3G_2	1.22	0.92
F_3G_3	0.96	0.95
SEm (±)	0.05	0.05
CD (P=0.05)	NS	0.133

NS: Not Significant

4.1.7 Quality analysis of top feeds

4.1.7.1. Crude protein content

The data pertaining to the crude protein content as influenced by cropping system, top feeds and spacing and their interaction are presented in Tables 30a, 30b and 30c.

The results revealed that intercropping had significant influence on crude protein content of top feed in first year (20.62%), however, it did not vary significantly in the second year. Regarding different top feeds, crude protein content differed significantly in first year andsecond year. In both the years, agathi had higher crude protein content (24.62 % and 24.77 % respectively) and drumstick had the lowest value (17.10 % and 17.82 % respectively). Similarly, crude protein content of top feeds vary with their planting geometry. In first year higher crude protein content was noticed in paired system of planting (20.69%) and it was statistically on par with G_2 (20.39%) whereas G_2 had significantly higher crude protein content in the second year (21.08%)

Interaction effect of cropping system and top feeds and cropping system and planting geometry did not vary significantly in both first and second year, however there was significant variation in crude protein content of top feeds in second year with respect to the interaction between top feed and planting geometry. The treatment combination F_1G_2 recorded significantly higher value of 25.61 per cent in the second year.

Crude protein content recorded significant variation with respect to interaction between cropping system, top feeds and planting geometry in the second year. The treatment combination $C_1F_1G_2$ recorded higher crude protein (25.72 %) and it was comparable with $C_2F_1G_1$ and $C_2F_1G_2$.

Table 30 a. Effect of cropping system, top feeds and planting geometry on crude protein content of top feeds, per cent

Treatments	Crude protein content	
	First year	Second year
Cropping system (C)		
C_1: Sole crop (Top feeds)	19.79	20.46
C_2 :Intercrop(Bajra Napier Hybrid)	20.62	20.54
SEm (±)	0.13	0.07
CD (P=0.05)	0.807	NS
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	24.62	24.77
F_2: *Erythrina* (*Erythrina indica*)	18.90	18.92
F_3: Drumstick (*Moringa oleifera*)	17.10	17.82
SEm (±)	0.15	0.13
CD (P=0.05)	0.479	0.436
Planting geometry (G)		
G_1: 2 m x 1 m	19.54	20.59
G_2: 2 m x 0.5 m	20.39	21.08
G_3: Paired system	20.69	19.84
SEm (±)	0.17	0.14
CD (P=0.05)	0.483	0.417

NS: Not Significant

Table 30b. Effect of C x F, C x G and F x G interactions on crude protein content of top feeds, per cent

Treatments	Crude protein content	
	First year	**Second year**
C_1F_1	24.22	24.72
C_1F_2	18.20	18.63
C_1F_3	16.96	18.04
C_2F_1	25.03	24.82
C_2F_2	19.60	19.21
C_2F_3	19.00	17.60
SEm (±)	0.21	0.19
CD (P=0.05)	NS	NS
C_1G_1	19.16	20.43
C_1G_2	20.08	20.94
C_1G_3	20.14	20.02
C_2G_1	19.93	20.75
C_2G_2	20.70	21.21
C_2G_3	21.24	19.67
SEm (±)	0.23	0.20
CD (P=0.05)	NS	NS
F_1G_1	23.82	24.81
F_1G_2	24.85	25.61
F_1G_3	25.20	23.90
F_2G_1	18.48	18.62
F_2G_2	19.04	19.65
F_2G_3	19.19	18.49
F_3G_1	16.33	18.35
F_3G_2	17.29	17.98
F_3G_3	17.67	17.14
SEm (±)	0.29	0.25
CD (P=0.05)	NS	0.723

NS: Not Significant

Table 30c. Interaction effect of cropping system, top feeds and planting geometry on crude protein content of top feeds, per cent

Treatments	**Crude protein content**	
	First year	**Second year**
$C_1F_1G_1$	23.27	24.37
$C_1F_1G_2$	24.33	25.72
$C_1F_1G_3$	25.07	24.08
$C_1F_2G_1$	17.71	18.49
$C_1F_2G_2$	18.89	18.52
$C_1F_2G_3$	18.00	18.87
$C_1F_3G_1$	16.50	18.43
$C_1F_3G_2$	17.03	18.59
$C_1F_3G_3$	17.34	17.10
$C_2F_1G_1$	24.37	25.24
$C_2F_1G_2$	25.38	25.50
$C_2F_1G_3$	25.33	23.72
$C_2F_2G_1$	19.25	18.75
$C_2F_2G_2$	19.19	20.77
$C_2F_2G_3$	20.38	18.10
$C_2F_3G_1$	16.17	18.26
$C_2F_3G_2$	17.55	17.37
$C_2F_3G_3$	18.00	17.18
SEm (±)	0.41	0.35
CD (P=0.05)	NS	1.022

NS: Not Significant

4.1.7.2. Crude fibre content

The data on effect of cropping system, top feeds and spacing on crude fibre content of top feeds in first and second year are furnished in Tables 31a, 31b and 31c.

The results revealed that crude fibre content of top feed did not vary significantly with cropping system in first year; however there was significant variation in second year. Intercropping top feed with Bajra Napier hybrid had the lowest crude fibre content in second year (14.47%). Crude fibre content of different top feeds varied significantly in both years and agathi recorded significantly the lowest crude fibre content in both years (8.24 and 8.81 per cent respectively), whereas crude fibre content of *Erythrina* was significantly the highest in both the years (18.44 and 18.66 per cent respectively). Regarding sub- sub plot factor, cultivating top feeds at 2 m x 1m geometry (G_1) had lower crude fibre content in first year (14.20 %) and it was on par with G_2 (2m x 0.5m). However crude fibre did not vary significantly in second year with respect to planting geometry.

The crude fibre content in response to interaction between cropping system and spacing did not vary significantly in both years. However, crude fibre content had significant influence on interaction between cropping system and spacing in second year. Treatment combination C_1G_3 lower crude fibre content in second year. Significant interaction between top feed and spacing was observed in crude fibre content of top feeds only during first year and F_1G_3 recorded the lowest value.

Interaction between cropping system, top feeds and planting geometry did not have any influence on crude fibre content of top feeds.

Table 31a. Effect of cropping system, top feeds and planting geometry on crude fibre content of top feeds, per cent

Treatments	Crude fibre content	
	First year	Second year
Cropping system (C)		
C_1: Sole crop (Top feeds)	14.73	15.40
C_2 :Intercrop(Bajra Napier Hybrid)	14.40	14.47
SEm (±)	0.21	0.10
CD (P=0.05)	NS	0.628
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	8.24	8.81
F_2: *Erythrina* (*Erythrina indica*)	18.44	18.66
F_3: Drumstick (*Moringa oleifera*)	17.01	17.33
SEm (±)	0.17	0.20
CD (P=0.05)	0.558	0.662
Planting geometry (G)		
G_1: 2 m x 1 m	14.20	15.17
G_2: 2 m x 0.5 m	14.59	15.01
G_3: Paired system	14.91	14.63
SEm (±)	0.18	0.20
CD (P=0.05)	0.517	NS

NS: Not Significant

Table 31b. Effect of C x F, C x G and F x G interactions on crude fibre content of top feeds, per cent

Treatments	Crude fibre content	
	First year	**First year**
C_1F_1	8.34	8.01
C_1F_2	18.74	18.57
C_1F_3	17.10	16.84
C_2F_1	8.15	9.61
C_2F_2	18.14	18.76
C_2F_3	16.91	17.83
SEm (±)	0.24	0.29
CD (P=0.05)	NS	NS
C_1G_1	14.20	15.23
C_1G_2	14.75	14.34
C_1G_3	15.23	13.85
C_2G_1	14.19	15.11
C_2G_2	14.42	15.69
C_2G_3	14.58	15.40
SEm (±)	0.25	0.28
CD (P=0.05)	NS	0.827
F_1G_1	8.43	8.61
F_1G_2	8.42	8.84
F_1G_3	7.87	8.99
F_2G_1	18.02	19.53
F_2G_2	18.28	18.49
F_2G_3	19.03	17.97
F_3G_1	16.14	17.37
F_3G_2	17.06	17.71
F_3G_3	17.82	16.91
SEm (±)	0.31	0.35
CD (P=0.05)	0.895	NS

Table 31 c. Effect of cropping system, top feeds and planting geometry on crude fibre content of top feeds, per cent

Treatments	**Crude fibre content**	
	First year	**Second year**
$C_1F_1G_1$	8.55	8.15
$C_1F_1G_2$	8.27	8.24
$C_1F_1G_3$	8.19	7.66
$C_1F_2G_1$	17.93	20.48
$C_1F_2G_2$	18.34	17.59
$C_1F_2G_3$	19.95	17.63
$C_1F_3G_1$	16.12	17.06
$C_1F_3G_2$	17.63	17.19
$C_1F_3G_3$	17.56	16.26
$C_2F_1G_1$	8.30	9.06
$C_2F_1G_2$	8.57	9.43
$C_2F_1G_3$	7.56	10.33
$C_2F_2G_1$	18.11	18.57
$C_2F_2G_2$	18.21	19.39
$C_2F_2G_3$	18.10	18.31
$C_2F_3G_1$	16.17	17.68
$C_2F_3G_2$	16.48	18.23
$C_2F_3G_3$	18.08	17.57
SEm (±)	0.43	0.49
CD (P=0.05)	NS	NS

4.1.8 Quality analysis of Bajra Napier hybrid

4.1.8.1. Crude protein content

The data pertaining to the crude protein content as influenced by top feeds and spacing and are given in Table 32. The results revealed that the crude protein content varied significantly with respect to top feeds and planting geometry in both the years.

Regarding Bajra Napier hybrid as intercrop with top feeds, significantly higher crude protein was noticed when Bajra Napier hybrid was intercropped with agathi in both the years (9.33% and 9.74% respectively). However significantly lowest content was in drum stick in first year (8.64%) and second year (8.49%). With respect to planting geometry of top feeds, significantly higher chlorophyll content was noticed by G_2 in both the years (9.29% and 9.18 per cent respectively in first and second year).

Among the treatment combinations, no significant interaction between top feeds and planting geometry with respect to crude protein content was observed in both the years.

4.1.8.2 Crude fibre content

The data on effect of top feeds and spacing on crude fibre content in Bajra Napier hybrid in first and second year are furnished in Table 33.

The results revealed that crude fibre content of Bajra Napier hybrid did not vary significantly with different top feeds in second year, whereas significantly the highest crude fibre content of 33.05 per cent was observed with drumstick during first year

The planting geometry of top feeds did not have any significant effect on crude fibre content of Bajra Napier hybrid in both the years.

Interaction between top feeds and planting geometry did not have any influence on crude fibre content of Bajra Napier hybrid in both the years.

Table 32. Effect of top feeds, planting geometry and F x G interaction on crude protein content of Bajra Napier hybrid, per cent

Treatments	Crude protein	
	First year	**Second year**
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	9.33	9.74
F_2: *Erythrina* (*Erythrina indica*)	9.03	8.55
F_3: Drumstick (*Moringa oleifera*)	8.64	8.49
SEm (±)	0.06	0.04
CD (P=0.05)	0.243	0.169
Planting geometry (G)		
G_1: 2 m x 1 m	8.92	8.86
G_2: 2 m x 0.5 m	9.29	9.18
G_3: Paired system	8.79	8.73
SEm (±)	0.07	0.11
CD (P=0.05)	0.232	0.355
Interaction (FxG)		
F_1G_1	9.19	9.71
$F1G_2$	9.78	9.96
F_1G_3	9.01	9.56
F_2G_1	8.93	8.27
F_2G_2	9.17	8.98
F_2G_3	9.00	8.21
F_3G_1	8.63	8.60
F_3G_2	8.93	8.61
F_3G_3	8.36	8.44
SEm (±)	0.10	0.07
CD (P=0.05)	NS	NS

NS: Not Significant

Table 33. Effect of top feeds, planting geometry and F x G interaction on crude fibre content of Bajra Napier hybrid, per cent

Treatments	**Crude fibre**	
	First year	**Second year**
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	32.97	33.14
F_2: *Erythrina* (*Erythrina indica*)	32.57	31.86
F_3: Drumstick (*Moringa oleifera*)	33.05	32.99
SEm (±)	0.09	0.51
CD (P=0.05)	0.361	NS
Planting geometry (G)		
G_1: 2 m x 1 m	33.83	33.04
G_2: 2 m x 0.5 m	32.58	32.68
G_3: Paired system	32.18	32.26
SEm (±)	0.51	0.54
CD (P=0.05)	NS	NS
Interaction (FxG)		
F_1G_1	33.37	33.34
$F1G_2$	31.90	32.89
F_1G_3	33.63	33.18
F_2G_1	32.97	33.30
F_2G_2	32.17	30.79
F_2G_3	32.57	31.49
F_3G_1	35.14	32.49
F_3G_2	33.67	34.37
F_3G_3	30.35	32.12
SEm (±)	0.16	0.88
CD (P=0.05)	NS	NS

NS : Not Significant

4.1.9 Competitive indices

The data on competitive indices like Land Equivalent Ratio (LER), Competition Ratio (CR), Aggressivity, Relative Crowding Coefficient (RCC), Area Time Equivalent Ratio (ATER) and Monetary Advantage Index (MAI) as influenced by top feeds and spacing in first year and second year are presented in Table 34. The data are presented as combined mean of two years.

4.1.9.1 Land Equivalent Ratio (LER)

The data on mean LER value of two years revealed that among different combinations, highest value of 2.37 was noticed by F_1G_2 (intercropping Bajra Napier hybrid with agathi in 2 m x 0.5 m geometry) followed by F_3G_1 (2.35). However the lowest LER value of 1.07 was noticed by drumstick intercropped Bajra Napier hybrid in paired system of geometry (F_3G_3).

4.1.9.2 Competitive Ratio (CR)

The result revealed that among different treatment combinations, higher competition ratio of 3.35 recorded by F_1G_3 (agathi in paired geometry) followed by F_3G_1 (drumstick in 2 m x 1 m geometry). Intercropping Bajra Napier hybrid with *Erythrina* in 2 m x 0.5 m (F_2G_2) recorded with lowest CR value of 1.32.

4.1.9.3 Aggressivity

The data on aggressivity of different treatment combinations revealed that top feeds recorded positive value and Bajra Napier hybrid was negative. The positive value implies that top feeds were aggressive or highly competitive than Bajra Napier which is competitively inferior in nature.Among different treatment combinations, the highest aggressivity of 1.19 was noticed in F_3G_1 (drumstick in 2 m x 1 m geometry) followed by agathi in 2 m x 0.5 m geometry (1.10). However lowest aggressivity value of 0.20 was noticed by F_2G_2 (*Erythrina* with 2 m x 0.5 m geometry).

4.1.9.4 Relative Crowding Coefficient (RCC)

The results revealed that the highest mean RCC value was noticed in F_2G_1 (24.34) followed by in F_2G_2 (7.64). Whereas the lowest value of -0.70 had observed in F_3G_3.

4.1.9.5 Area Time Equivalent Ratio (ATER)

Among the different treatment combinations, the highest mean ATER value of 2.37 was observed in F_1G_2 followed by F_3G_1 (2.35).Among the treatment combinations, the lowest mean ATER value of 1.07 was recorded when drumstick was intercropped with Bajra Napier hybrid in paired system (1.07).

4.1.9.6 Monetary advantage Index (MAI)

The results of the study revealed that the highest MAI of 158920 was noticed when agathi was intercropped with Bajra Napier hybrid at 2 m x 0.5 m geometry (F_1G_2) followed by F_3G_2 (125994). Among the treatment combinations, *Erythrina* in paired system (F_2G_3) recorded lowest MAI of 42166.

Table 34. Effect of top feeds and planting geometry on Land Equivalent Ratio (LER), Land Equivalent Coefficient (LEC),Competitive Ratio (CR), aggressivity, Relative Crowding Coefficient (RCC), Area Time Equivalent Ratio (ATER) and Monetary advantage Index (MAI) (Combined mean value of two years)

Treatments	LER	CR	Aggressivity		RCC	ATER	MAI
			Top feed	Bajra Napier hybrid			
$C_1F_1G_1$	1.89	2.20	+0.71	-0.71	-5.39	1.89	109364
$C_1F_1G_2$	2.37	2.73	+1.10	-1.14	-3.45	2.37	158920
$C_1F_1G_3$	1.64	3.35	+0.88	-1.01	-3.52	1.64	72247
$C_1F_2G_1$	1.59	1.45	+0.29	-0.31	24.34	1.59	73506
$C_1F_2G_2$	1.47	1.32	+0.20	-0.17	7.64	1.47	62536
$C_1F_2G_3$	1.37	1.68	+0.35	-0.38	5.32	1.37	42166
$C_1F_3G_1$	2.35	3.05	+1.19	-1.24	-2.71	2.35	125630
$C_1F_3G_2$	1.16	1.41	+0.55	-1.25	-1.87	1.16	125994
$C_1F_3G_3$	1.07	2.35	+0.69	-1.53	-0.70	1.07	96326

4.1.10 Nutrient uptake of top feeds

The data with respect to nitrogen, phosphorus and potassium uptake of top feeds during first year and second year of the study are presented in Tables 35a, 35b and 35c

4.1.10.1 Nitrogen uptake

Intercropping had significant effect on nitrogen uptake of top feeds and growing top feeds along with Bajra Napier hybrid (C_2) had significantly higher nitrogen uptake in both the years (50.66 kg ha^{-1} in first year and 54.27 $kgha^{-1}$ in second year). Considering three different top feeds, agathi recorded significantly higher nitrogen uptake in both the years (73.94 kg ha^{-1} and 79.42 kg ha^{-1} respectively) and *Erythrina* had the lowest nitrogen uptake in first (34.39 kg ha^{-1}) and second (37.18 kg ha^{-1}) years. Among three planting geometry, growing top feeds under paired system of planting (G_3) had significantly higher N uptake in both the years (53.06 kg ha^{-1} and 56.46 kg ha^{-1} respectively).

Interaction between cropping system and top feeds significantly influenced the nutrient uptake of top feeds in both the years treatment combination C_2F_1 had significantly higher nitrogen uptake in first year (77.58 kg ha^{-1}) and in second year (81.66 kg ha^{-1}). However the interaction effect between cropping system and planting geometry was not significant in first year. But significantly higher value of 57.07 kg ha^{-1} was recorded by the treatment C_2G_2 in second year and it was on par with C_2G_3 and C_1G_2.The results also revealed that the interaction between top feeds and planting geometry had significant influence on the N uptake of top feeds and F_1G_2 was observed with higher value in both first (84.25 kg ha^{-1}) and second year (86.86 kg ha^{-1}).However the value was on par with F_1G_3 in the second year.

The nitrogen uptake of top feeds varied significantly with the interaction between cropping system, top feed and planting. The study revealed that higher N uptake was noticed in $C_2F_1G_2$ in first year (88.50 kg ha^{-1}) and second year (92.26 kg ha^{-1}) and it was on par with $C_2F_1G_3$ in both the years.

4.1.10.2 Phosphorus uptake

Cropping system had no significant effect on phosphorus uptake of top feeds in both the years. Whereas different top feeds had significant effect on P uptake of top feeds and during both the years, agathi absorbed more phosphorus from the soil (38.67 kg ha^{-1} and 42.57 kg ha^{-1}). However in second year, agathi was on par with drumstick with respect to P uptake. Regarding planting geometry, P uptake of top feeds significantly varied in second year and paired system of planting had significantly higher value (39.90 kg ha^{-1}).

Interaction between cropping system and top feeds had significant influence on phosphorus uptake of top feeds during first year and significantly higher value was noticed in C_2F_1 (42.88 kg ha^{-1}).However, C_2F_3 recorded the highest P uptake during second year (45.87 kg ha^{-1}) and it was on par with C_2F_1 and C_1F_1. Interaction between cropping system and top feeds and top feeds and planting geometry did not have any significant effect on the phosphorus uptake of top feeds.

The interaction between cropping system, top feed and planting geometry also did not have significant effect on the P uptake of top feeds.

4.1.10.3 Potassium uptake

The uptake of potassium by different top feeds varied significantly with cropping system and significantly higher uptake was noticed in intercropping system in both the years (93.30 kg ha^{-1} and 106.17 kg ha^{-1} respectively). Among different top feeds, agathi recorded significantly higher values during both the years (100.94 kg ha^{-1} and 114.44 kg ha^{-1} respectively).Regarding three planting geometry, G_2 recorded significantly higher K uptake in both the years (88.86 kg ha^{-1} and 98.67 kg ha^{-1} respectively)

Among different treatment combinations involving interaction between cropping system and top feeds, higher K uptake was noticed in C_2F_1 in both the years (115.59 kg ha^{-1} and 134.52 kg ha^{-1} respectively). Regarding the interaction between cropping system and planting geometry, significantly higher K uptake was noticed in C_2G_2 during first year (102.04 kg ha^{-1}) and second year (113.13 kg ha^{-1}).Likewise the interaction between top feeds and planting geometry had significant influence on the K uptake of top feeds and the treatment combination F_1G_2 recorded significantly higher value in both the years (122.08 kg ha^{-1}and 130.17 kg ha^{-1}respectively)

The interaction between cropping system, top feed and planting geometry had influence on K uptake of top feed and the treatment combination $C_2F_1G_2$ had significantly higher value in first year (138.27 kg ha^{-1}) and second year (145.65 kg ha^{-1}).

Table 35 a. Effect of cropping system, top feeds and planting geometry on nitrogen phosphorus and potassium uptake of top feeds during first year and second year. kg ha^{-1}

Treatments	**N uptake**		**P uptake**		**K uptake**	
	1st year	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
Cropping system (C)						
C_1: Sole crop	44.51	49.62	28.87	33.95	71.66	79.60
C_2 :Intercrop	50.66	54.27	30.68	37.46	93.30	106.17
SEm (±)	0.13	0.26	2.38	3.03	1.55	2.41
CD (P=0.05)	0.781	1.603	NS	NS	9.558	14.862
Top feeds (F)						
F_1: Agathi	73.94	79.42	38.67	42.57	100.94	114.44
F_2: *Erythrina*	34.39	37.18	20.21	24.97	55.53	63.09
F_3: Drumstick	34.42	39.24	30.44	39.58	90.97	101.13
SEm (±)	0.71	0.80	1.39	1.81	1.47	0.99
CD (P=0.05)	2.325	2.596	4.519	5.883	4.797	3.214
Planting geometry of top feed (G)						
G_1: 2 m x 1 m	42.46	46.37	28.18	32.19	83.60	92.70
G_2: 2 m x 0.5 m	53.06	56.46	29.85	39.90	88.86	98.67
G_3: Paired system	47.22	53.00	31.30	35.02	74.98	87.29
SEm (±)	0.74	0.97	1.20	0.93	1.43	1.66
CD (P=0.05)	2.146	2.822	NS	2.710	4.179	4.855

Table 35b. Interaction Effect of cropping system, top feeds and planting geometry on nitrogen phosphorus and potassium uptake of top feeds during first year and second year, kg ha^{-1}

Treatments	N uptake		P uptake		K uptake	
	1st year	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
C_1F_1	70.30	77.17	34.46	40.23	86.30	94.36
C_1F_2	37.76	41.60	23.16	28.32	59.08	66.19
C_1F_3	25.46	30.08	28.99	33.30	69.60	78.25
C_2F_1	77.58	81.66	42.88	44.90	115.59	134.52
C_2F_2	31.02	32.75	17.27	21.62	51.98	59.98
C_2F_3	43.37	48.39	31.89	45.87	112.34	124.00
SEm (±)	1.01	1.13	1.96	2.55	2.08	1.40
CD (P=0.05)	3.288	3.671	6.391	8.320	6.784	4.545
C_1G_1	38.40	42.00	27.58	30.07	77.40	84.10
C_1G_2	45.39	55.86	29.14	33.65	75.68	84.20
C_1G_3	49.73	51.00	29.88	38.13	61.90	70.49
C_2G_1	46.52	50.74	28.77	34.32	89.80	101.29
C_2G_2	49.06	57.07	30.55	36.40	102.04	113.13
C_2G_3	56.39	55.00	32.72	41.66	88.07	104.08
SEm (±)	1.04	1.37	1.69	1.31	2.02	2.35
CD (P=0.05)	NS	3.991	NS	NS	5.911	6.866
F_1G_1	60.79	67.13	34.35	38.46	104.50	115.83
F_1G_2	84.25	86.86	40.39	43.71	122.08	130.17
F_1G_3	76.78	84.26	41.29	45.53	76.24	97.31
F_2G_1	33.10	33.67	21.08	24.01	50.06	57.25
F_2G_2	32.47	35.95	17.90	21.33	60.16	67.97
F_2G_3	37.59	41.91	21.66	29.56	56.38	64.05
F_3G_1	33.48	38.31	29.10	34.11	96.24	105.01
F_3G_2	32.42	38.78	31.25	40.04	84.34	97.87
F_3G_3	37.35	40.62	30.96	44.61	92.32	100.50
SEm (±)	1.27	1.67	2.07	1.61	2.48	2.88
CD (P=0.05)	3.716	4.888	NS	NS	7.239	8.409

NS: Not Significant

Table 35c. Interaction Effect of cropping system, top feeds and planting geometry on nitrogen phosphorus and potassium uptake of top feeds during first year and second year, kg ha^{-1}

Treatments	N uptake		P uptake		K uptake	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
$C_1F_1G_1$	62.77	67.38	33.30	37.44	91.75	100.07
$C_1F_1G_2$	68.14	76.26	35.52	38.56	105.90	114.68
$C_1F_1G_3$	80.00	85.27	34.57	44.70	61.25	68.32
$C_1F_2G_1$	28.26	31.11	24.89	25.49	53.75	60.07
$C_1F_2G_2$	41.96	44.79	22.01	26.59	63.95	69.08
$C_1F_2G_3$	43.06	48.91	22.57	32.88	59.53	69.43
$C_1F_3G_1$	24.18	27.51	24.56	27.29	86.70	92.17
$C_1F_3G_2$	26.06	31.93	29.91	35.79	57.18	68.85
$C_1F_3G_3$	26.14	30.80	32.49	36.83	64.92	73.74
$C_2F_1G_1$	58.82	66.88	35.39	39.48	117.26	131.59
$C_2F_1G_2$	88.50	92.26	45.26	48.86	138.27	145.66
$C_2F_1G_3$	85.41	87.87	48.00	46.36	91.24	126.31
$C_2F_2G_1$	37.94	36.23	17.28	22.54	46.36	54.44
$C_2F_2G_2$	22.98	27.11	13.80	16.06	56.37	66.85
$C_2F_2G_3$	32.12	34.91	20.74	26.24	53.22	58.67
$C_2F_3G_1$	42.79	49.12	33.65	40.93	105.78	117.85
$C_2F_3G_2$	38.78	45.63	32.60	44.28	111.50	126.89
$C_2F_3G_3$	48.55	50.43	29.43	52.40	119.73	127.25
SEm (±)	1.80	2.37	2.93	2.27	3.51	4.07
CD (P=0.05)	5.256	6.913	NS	NS	10.238	11.892

NS: Not Significant

4.1.11. Nutrient uptake of Bajra Napier hybrid

The data on nitrogen, phosphorus and potassium uptake of Bajra Napier hybrid are presented in Table 36.

4.1.11.1. Nitrogen uptake

The result revealed that different top feeds had no significant effect on nitrogen uptake of Bajra Napier hybrid. Considering planting geometry of top feeds, G_2 recorded the highest nitrogen uptake value in both the years (192.87 kg ha^{-1} and 200.96 kg ha^{-1} respectively) and the value was on par with G_1.The F x G interaction effect on nitrogen uptake of Bajra Napier hybrid was found to be non-significant.

4.1.11.2. Phosphorus uptake

Considering three different top feeds, phosphorus uptake value of Bajra Napier hybrid was significantly differed only in second year and higher value of 42.14 kg ha^{-1} was noticed in the Bajra Napier hybrid grown along with *Erythrina* (F_2). Among three planting geometry, the highest phosphorus uptake was in G_1 during first year (39.25 kg ha^{-1}) and it was on par with G_2. However, during the second year G_2 had higher phosphorus uptake (41.08 kg ha^{-1}) and it was on par with G_1.

The interaction between top feeds and planting geometry showed variation with respect to phosphorus uptake in both the years. F_2G_1 recorded the highest values in both the years (45.07 kg $ha^{-1}$and 47.75 kg ha^{-1} respectively).In both the years, F_2G_1 was comparable with F_1G_2 and F_2G_2.

4.1.11.3. Potassium uptake

Among three different main plot treatments, agathi had the highest potassium uptake during both the years (224.48 kg $ha^{-1}$and 244.34 kg ha^{-1} respectively) and in the second year it was on par with *Erythrina*. Regarding the sub plot treatment, G_2 had higher potassium uptake during first year (222.44 kg ha^{-1}) and it was on par with G_1.However, G_1 recorded with the highest potassium uptake (246.95 kg ha^{-1}) in second year and it was on par with G_2.

The interaction between top feeds and planting geometry were significantly varied in first year and significantly higher K uptake was noticed in F_1G_1 (262.73 kg ha^{-1}). However the interaction was non -significant during second year.

Table 36. Effect of top feeds and planting geometry on nitrogen phosphorus and potassium uptake of Bajra Napier hybrid during first year and second year, kg ha^{-1}

Treatments	**N uptake**		**P uptake**		**K uptake**	
	1st year	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
F_1: Agathi	166.21	169.79	32.74	35.40	224.48	244.34
F_2: *Erythrina*	182.24	190.20	37.88	42.14	196.35	237.73
F_3: Drumstick	159.36	169.44	31.65	31.85	203.34	230.55
SEm (±)	4.72	4.91	1.50	0.61	1.68	2.07
CD (P=0.05)	NS	NS	NS	2.467	6.769	8.350
Planting geometry of top feed (G)						
G_1: 2 m x 1 m	186.14	194.50	39.25	40.18	215.40	246.95
G_2: 2 m x 0.5 m	192.88	200.96	39.21	41.08	222.44	243.25
G_3: Paired system	128.80	133.96	23.80	28.14	186.34	222.41
SEm (±)	2.33	2.80	1.35	1.50	3.36	5.68
CD (P=0.05)	7.249	8.719	4.193	4.660	10.459	17.7
Interaction						
F_1G_1	185.69	187.29	33.20	34.75	262.73	251.45
$F1G_2$	189.90	196.40	42.99	44.46	235.10	253.59
F_1G_3	123.04	125.68	22.01	26.98	175.63	227.96
F_2G_1	198.98	207.10	45.07	47.76	167.51	249.61
F_2G_2	207.55	216.67	38.15	40.09	208.30	231.86
F_2G_3	140.18	146.82	30.40	38.59	213.25	231.72
F_3G_1	173.74	189.11	39.48	38.04	215.96	239.79
F_3G_2	181.18	189.82	36.48	38.69	223.91	244.31
F_3G_3	123.17	129.39	18.99	18.84	170.16	207.55
SEm (±)	8.18	8.51	2.60	1.06	2.91	3.59
CD (P=0.05)	NS	NS	8.084	8.255	18.708	NS

4.1.10 Carbon sequestration potential of the system

Tables 37a, 37b and 37c represent the effect of cropping system, top feeds and planting geometry on carbon sequestration potential of the system in first year and second year.

The results revealed that growing top feeds along with Bajra Napier hybrid (C_2) had significantly higher level of carbon sequestration than growing top feed as a sole crop (C_1) in both the years (24.57 t ha^{-1} and 25.59 t ha^{-1} respectively). Considering different top feeds, agathi recorded significantly higher carbon sequestration potential in both the years (18.15 t ha^{-1} and 18.91 t ha^{-1} respectively). *Erythrina* sequestered significantly the lowest level of carbon in first year (17.24 t ha^{-1}) and in second year (17.37 t ha^{-1} yr^{-1}). Among three planting geometry, G_2 had significantly higher carbon sequestration in first year (18.13 t ha^{-1} yr^{-1}) and second year (18.87 t ha^{-1}).

The interaction between cropping system and top feeds significantly varied with respect to carbon sequestration potential of the system and higher value was noticed by C_2F_1 in both the years (26.15 t ha^{-1} and 26.22 t ha^{-1} respectively). However considering the interaction between cropping system and planting geometry, C_2G_2 had significantly higher carbon sequestration potential in both the years (26.87 t ha^{-1} and 26.74 t ha^{-1} respectively). The interaction between top feeds and planting geometry varied significantly with respect to the carbon sequestration potential in both the years and significantly higher value was noticed in F_1G_2 (19.14t ha^{-1} and 19.08 t ha^{-1} respectively in first year and second year).

Significant interaction between cropping system, top feeds and planting geometry was noticed in carbon sequestration potential of the system in both the years. $C_2F_1G_2$ recorded significantly higher level of carbon sequestration in first year (28.09 t ha^{-1}) and second year (28.13 t ha^{-1}).

Table 37a: Effect of cropping system, top feeds and planting geometry on carbon sequestration potential of the system, t ha^{-1}

Treatments	**Carbon sequestration potential**	
	First year	**Second year**
Cropping system (C)		
C_1: Sole crop (Top feeds)	9.55	9.72
C_2 :Intercrop(Bajra Napier Hybrid)	24.57	25.59
SEm (±)	0.02	0.02
CD (P=0.05)	0.074	0.135
Top feeds (F)		
F_1: Agathi (*Sesbania grandiflora*)	18.15	18.91
F_2: *Erythrina* (*Erythrina indica*)	17.24	17.37
F_3: Drumstick (*Moringa oleifera*)	17.29	17.38
SEm (±)	0.02	0.03
CD (P=0.05)	0.070	0.085
Planting geometry (G)		
G_1: 2 m x 1 m	17.88	18.04
G_2: 2 m x 0.5 m	18.13	18.87
G_3: Paired system	16.67	16.64
SEm (±)	0.03	0.03
CD (P=0.05)	0.074	0.092

Table 37b. Effect of C x F, C x G and F x G interactions on on carbon sequestration potential of the system, t ha^{-1}

Treatments	Carbon sequestration potential	
	First year	Second year
C_1F_1	10.27	10.08
C_1F_2	9.38	9.24
C_1F_3	9.51	9.33
C_2F_1	26.15	26.22
C_2F_2	25.35	25.23
C_2F_3	25.26	25.24
SEm (±)	0.030	0.04
CD (P=0.05)	0.098	0.120
C_1G_1	9.63	9.51
C_1G_2	9.68	9.51
C_1G_3	9.85	9.63
C_2G_1	26.46	26.24
C_2G_2	26.87	26.74
C_2G_3	23.44	23.71
SEm (±)	0.036	0.044
CD (P=0.05)	0.105	0.129
F_1G_1	18.46	18.30
F_1G_2	19.14	19.08
F_1G_3	17.04	17.07
F_2G_1	17.76	17.58
F_2G_2	17.80	17.62
F_2G_3	16.54	16.52
F_3G_1	17.91	17.75
F_3G_2	17.88	17.68
F_3G_3	16.36	16.43
SEm (±)	0.044	0.054
CD (P=0.05)	0.129	0.158

Table 37c: Interaction effect of cropping system, top feeds and planting geometry on carbon sequestration potential of the system, t ha^{-1}

Treatments	Carbon sequestration potential	
	First year	**First year**
$C_1F_1G_1$	10.13	9.97
$C_1F_1G_2$	10.19	10.03
$C_1F_1G_3$	10.49	10.23
$C_1F_2G_1$	9.30	9.20
$C_1F_2G_2$	9.36	9.27
$C_1F_2G_3$	9.49	9.27
$C_1F_3G_1$	9.46	9.37
$C_1F_3G_2$	9.48	9.23
$C_1F_3G_3$	9.59	9.40
$C_2F_1G_1$	26.79	26.63
$C_2F_1G_2$	28.09	28.13
$C_2F_1G_3$	23.59	23.90
$C_2F_2G_1$	26.23	25.97
$C_2F_2G_2$	26.24	25.97
$C_2F_2G_3$	23.58	23.77
$C_2F_3G_1$	26.36	26.13
$C_2F_3G_2$	26.28	26.13
$C_2F_3G_3$	23.13	23.47
SEm (±)	0.062	0.077
CD (P=0.05)	0.182	0.224

4.1.12. Nutrient status of the soil after the experiment

Tables 38a, 38b, 38c, 39a, 39b and 39c shows the data on pH, EC organic carbon, available nitrogen, phosphorus potassium, and EC content of soil after the experiment.

4.1.12.1 Organic Carbon

The results revealed that the organic carbon content of the soil after the experiment was not significantly influenced by cropping system and planting geometry of top feeds. Among three different top feeds, highest organic carbon content was noticed in agathi (1.26%) and it was on par with *Erythrina* (1.23%).

Considering the interaction between cropping system and top feeds, C_2F_1 recorded significantly higher organic carbon content of 1.30 per cent after the experiment and it was on par with C_2F_3 and C_2F_2. Whereas interaction between cropping system and planting geometry and top feed and planting geometry were found to be not significant with respect to organic carbon content.

Regarding the interaction between cropping system, top feeds and planting geometry, higher organic carbon was noticed in $C_2F_1G_2$ (1.43%) and it was on par with $C_1F_2G_1$, $C_1F_3G_2$, $C_1F_3G_2$, $C_1F_3G_3$, $C_1F_1G_2$, $C_2F_2G_3$, $C_2F_3G_1$, $C_2F_3G_2$.

4.1.12.2 Soil pH

The results revealed that treatments involving cropping system, feeds and planting geometry had no significant effect on pH of the soil after the experiment. Similarly Interaction was also non-significant with respect to pH status of the soil.

4.1.12.3 Electrical conductivity

The results of the experiment revealed that treatments like cropping system, top feeds and planting geometry had no significant influence on the electrical conductivity of the soil after the experiment. Similarly the interactions were also not significant

Table 38a: Effect of cropping system, top feeds and planting geometry on organic carbon content, pH and EC of soil after the experiment

Treatments	Organic Carbon (%)	pH	EC (dS m^{-1})
Cropping system (C)			
C_1: Sole crop (Top feeds)	1.18	5.45	0.85
C_2 :Intercrop(Bajra Napier Hybrid)	1.19	5.44	0.85
SEm (±)	0.01	0.00	0.00
CD (P=0.05)	NS	NS	NS
Top feeds (F)			
F_1: Agathi (*Sesbania grandiflora*)	1.26	5.44	0.85
F_2: *Erythrina* (*Erythrina indica*)	1.23	5.45	0.86
F_3: Drumstick (*Moringa oleifera*)	1.06	5.44	0.85
SEm (±)	0.02	0.01	0.00
CD (P=0.05)	0.060	NS	NS
Planting geometry of top feeds (G)			
G_1: 2 m x 1 m	1.19	5.45	0.85
G_2: 2 m x 0.5 m	1.24	5.45	0.85
G_3: Paired system	1.13	5.43	0.85
SEm (±)	0.03	0.01	0.00
CD (P=0.05)	NS	NS	NS

NS: Not Significant

Table 38b. Effect of C x F, C x G and F x G interactions on organic carbon, pH and EC of soil after the experiment

Treatments	**Organic Carbon content**	**pH**	**EC (dS m^{-1})**
C_1F_1	1.01	5.44	0.85
C_1F_2	1.10	5.44	0.86
C_1F_3	1.16	5.45	0.85
C_2F_1	1.30	5.44	0.86
C_2F_2	1.23	5.45	0.85
C_2F_3	1.30	5.44	0.85
SEm (±)	0.03	0.01	0.00
CD (P=0.05)	0.085	NS	NS
C_1G_1	1.22	5.44	0.86
C_1G_2	1.21	5.44	0.85
C_1G_3	1.12	5.44	0.86
C_2G_1	1.15	5.44	0.85
C_2G_2	1.27	5.44	0.86
C_2G_3	1.13	5.44	0.85
SEm (±)	0.048	0.008	0.004
CD (P=0.05)	NS	NS	NS
F_1G_1	1.08	5.45	0.85
F_1G_2	1.13	5.45	0.85
F_1G_3	0.97	5.42	0.86
F_2G_1	1.17	5.45	0.86
F_2G_2	1.25	5.46	0.86
F_2G_3	1.27	5.44	0.86
F_3G_1	1.31	5.45	0.85
F_3G_2	1.34	5.44	0.86
F_3G_3	1.14	5.45	0.85
SEm (±)	0.059	0.006	0.005
CD (P=0.05)	NS	NS	NS

NS: Not Significant

Table 38 c: Interaction effect of cropping system, top feeds and planting geometry on on organic carbon, pH and EC of soil after the experiment

Treatments	**Organic Carbon content per cent**	**pH**	**EC (dS m^{-1})**
$C_1F_1G_1$	1.18	5.45	0.86
$C_1F_1G_2$	0.89	5.45	0.84
$C_1F_1G_3$	0.96	5.43	0.86
$C_1F_2G_1$	1.29	5.44	0.86
$C_1F_2G_2$	1.36	5.46	0.85
$C_1F_2G_3$	1.19	5.44	0.86
$C_1F_3G_1$	1.19	5.45	0.85
$C_1F_3G_2$	1.29	5.46	0.87
$C_1F_3G_3$	1.22	5.44	0.85
$C_2F_1G_1$	0.98	5.46	0.85
$C_2F_1G_2$	1.43	5.45	0.86
$C_2F_1G_3$	0.98	5.40	0.86
$C_2F_2G_1$	1.05	5.46	0.85
$C_2F_2G_2$	1.07	5.46	0.86
$C_2F_2G_3$	1.35	5.45	0.85
$C_2F_3G_1$	1.43	5.44	0.85
$C_2F_3G_2$	1.38	5.42	0.85
$C_2F_3G_3$	1.07	5.46	0.85
SEm (±)	0.08	0.02	0.01
CD (P=0.05)	0.243	NS	NS

NS: Not Significant

4.1.12.4 Available nitrogen

The treatments involving cropping system, top feed and planting geometry had no significant effect on available nitrogen status of the soil after the experiment. Likewise, C x F, C x G, F x G and C x F x G interaction were also not significant.

4.1.12.5 Available phosphorus

Cropping system had significant influence on the available phosphorus content of the soil after the experiment. Sole cropping recorded higher available P in the soil after the experiment (38.27 kg ha^{-1}).Among different top feeds, *Erythrina* had noticed with higher phosphorus content in soil (36.52 kg ha^{-1}) after the experiment. However P content in soil after experiment was not significant with respect to planting geometry.

Interaction between cropping system and top feed failed to exhibit significant effect with respect to available phosphorus content in soil after the experiment. Similarly available P content in soil was not significant with respect to interaction between cropping system and planting geometry and top feeds and planting geometry.

Available P content in soil after experiment did not vary significantly with respect to the interaction between cropping system, top feeds and planting geometry.

4.1.12.5 Available Potassium

The result of the experiment revealed that available potassium content of the soil after the experiment significantly varied with different cropping systems and sole cropping had significantly higher potassium content of 155.29 kg ha^{-1}after the experiment. Similarly, top feeds also had significant effect on K content of the soil and significantly higher value was noticed by *Erythrina* (155.13 kg ha^{-1}).However regarding the planting geometry of top feeds, it was found to be not significant with respect to the available K content in soil.

The results also revealed that the interaction between cropping system and top feeds had no significant effect on the available potassium content in soil. But there was significant effect for the interaction between cropping system and planting geometry and the highest available potassium in soil was observed in C_1G_2 (160.19

kg ha^{-1}) and it was on par with C_1G_3..Likewise there was variation in available potassium content in soil with respect to top feeds and planting geometry. The treatment F_2G_3 showed higher potassium content of (167.93 kg ha^{-1}) and it was on par with F_3G_2 and F_2G_1.

The interaction between cropping system, top feeds and planting geometry was found to be non-significant with respect to the available potassium content in the soil after the experiment.

Table 39a. Effect of cropping system, top feeds and planting geometry on nitrogen, phosphorus and potassium status of soil after the experiment, kg ha^{-1}

Treatments	N	P	K
Main crop: Cropping system (C)			
C_1: Sole crop (Top feeds)	249.02	38.27	155.29
C_2 :Intercrop(Bajra Napier Hybrid)	248.56	35.37	125.34
SEm (±)	5.84	0.89	3.39
CD (P=0.05)	NS	2.592	20.912
Sub plot: Top feeds (F)			
F_1: Agathi (*Sesbania grandiflora*)	248.09	32.54	122.41
F_2: *Erythrina* (*Erythrina indica*)	256.46	36.52	155.13
F_3: Drumstick (*Moringa oleifera*)	241.82	28.00	143.40
SEm (±)	5.29	0.51	2.75
CD (P=0.05)	NS	1.652	8.963
Sub sub plot: Planting geometry (G)			
G_1: 2 m x 1 m	253.67	37.36	136.45
G_2: 2 m x 0.5 m	248.09	30.99	137.11
G_3: Paired system	244.61	37.10	147.38
SEm (±)	5.07	0.89	3.83
CD (P=0.05)	NS	NS	NS

Table 39b. Interaction effect of cropping system, top feeds and planting geometry on nitrogen, phosphorus and potassium status of soil after the experiment, kg ha^{-1}

Treatments	**N**	**P**	**K**
Cropping system (C)			
C_1F_1	246.70	35.02	134.66
C_1F_2	257.85	43.06	167.21
C_1F_3	242.52	36.74	164.00
C_2F_1	249.49	32.01	110.15
C_2F_2	255.06	36.84	143.05
C_2F_3	241.12	3.26	122.81
SEm (±)	7.48	0.72	3.89
CD (P=0.05)	NS	NS	NS
C_1G_1	262.03	36.51	149.72
C_1G_2	245.31	35.03	160.20
C_1G_3	239.73	38.28	155.95
C_2G_1	245.31	33.22	123.18
C_2G_2	250.88	31.96	114.02
C_2G_3	249.49	30.93	138.81
SEm (±)	7.18	1.26	5.41
CD (P=0.05)	NS	NS	15.805
F_1G_1	259.24	31.36	117.09
F_1G_2	246.70	29.67	105.12
F_1G_3	238.34	32.50	145.01
F_2G_1	252.97	36.67	150.83
F_2G_2	263.42	30.50	146.64
F_2G_3	252.97	29.67	167.93
F_3G_1	248.79	30.06	141.43
F_3G_2	234.16	31.80	159.57
F_3G_3	242.52	33.14	129.21
SEm (±)	8.79	0.54	6.63
CD (P=0.05)	NS	NS	19.355

NS: Not Significant

Table 39c. Interaction effect of cropping system, top feeds and planting geometry on nitrogen phosphorus and potassium status of soil after the experiment, kg ha^{-1}

Treatments	**N**	**P**	**K**
Cropping system (C)			
$C_1F_1G_1$	263.42	36.97	124.94
$C_1F_1G_2$	242.52	32.08	124.38
$C_1F_1G_3$	234.16	36.00	154.67
$C_1F_2G_1$	263.42	28.50	167.03
$C_1F_2G_2$	259.24	23.33	163.02
$C_1F_2G_3$	250.88	25.33	171.58
$C_1F_3G_1$	259.24	32.05	157.19
$C_1F_3G_2$	234.16	36.67	193.20
$C_1F_3G_3$	234.16	38.50	141.61
$C_2F_1G_1$	255.06	35.75	109.24
$C_2F_1G_2$	250.88	34.27	85.87
$C_2F_1G_3$	242.52	31.00	135.35
$C_2F_2G_1$	242.52	32.84	134.62
$C_2F_2G_2$	267.61	27.67	130.26
$C_2F_2G_3$	255.06	34.00	164.27
$C_2F_3G_1$	238.34	30.07	125.66
$C_2F_3G_2$	234.16	33.93	125.94
$C_2F_3G_3$	250.88	34.79	116.82
SEm (±)	12.43	2.18	9.38
CD (P=0.05)	NS	NS	NS

NS: Not Significant

4.1.13 Economics

Table 40 indicates the effect of cropping system, top feeds and planting geometry on economics of the system.

The results of the study revealed that the treatment combination $C_2F_1G_2$ had higher net returns (₹180070 ha^{-1}) and B:C ratio (2.89) followed by $C_2F_1G_1$ recorded net returns of ₹147613 ha^{-1} and B:C ratio of 2.73. Among the different treatment combinations, lowest net returns (₹5683 ha^{-1}) and B: C ratio (1.16) was registered by $C_1F_2G_1$.

Table 40. Effect of cropping system, top feeds and planting geometry on on economics of the system

Treatments	**Gross return (₹ ha^{-1})**	**Net income (₹ ha^{-1})**	**B:C ratio**
$C_1F_1G_1$	68050	26556	1.64
$C_1F_1G_2$	71448	31533	1.79
$C_1F_1G_3$	78138	39646	2.03
$C_1F_2G_1$	41202	5683	1.16
$C_1F_2G_2$	44174	7966	1.22
$C_1F_2G_3$	46106	19760	1.75
$C_1F_3G_1$	45454	8798	1.24
$C_1F_3G_2$	43514	6323	1.17
$C_1F_3G_3$	48960	19287	1.65
$C_2F_1G_1$	232938	147613	2.73
$C_2F_1G_2$	275345	180070	2.89
$C_2F_1G_3$	186022	97860	2.11
$C_2F_2G_1$	198094	119485	2.52
$C_2F_2G_2$	197022	112099	2.32
$C_2F_2G_3$	157690	87606	2.25
$C_2F_3G_1$	218690	122773	2.28
$C_2F_3G_2$	218637	132897	2.55
$C_2F_3G_3$	175935	91351	2.08

4.2 EXPERIMENT II: QUALITY ASSESSMENT OF PREDOMINANT FODDER TREES AND SHRUBS OF SOUTHERN KERALA FOR FEED QUALITY

4.2.1 Proximate analysis of tree fodder

The suitability of indigenous tree leaves as fodder is mainly decided by the proximate composition values and fibre fraction analysis. The proximate composition like dry matter content, crude protein, crude fibre, ether extract, total ash and nitrogen free extracts of tree fodder leaves were analysed and the results are furnished in Table 41a and 41b.

4.2.1.1 Dry matter content

The actual amount of feed material leaving water and volatile acid is referred to as dry matter (DM). The investigation on various tree fodders for DM content revealed that, *Cocos nucifera* recorded higher dry matter content of 66.14 per cent, followed by *Manihot esculenta* (48.50 %) and *Mangifera indica* (40.12 %). However, *Gliricidia maculata* had the lowest dry matter content of 22.50 per cent.

4.2.1.2 Crude protein content

The crude protein (CP) content of fodder tree leaves varied from 11.91 to 25.24 per cent. The highest crude protein content was noticed in *Sesbania grandiflora* (25.24 %) followed by *Leucaena leucocephala* (24.42 %). However *Musa acuminata* recorded the lowest value of 11.91 per cent.

4.2.1.3 Crude fibre content

Crude fibre content in the sample varied from 8.43 to 30 per cent. Among different tree fodders, *Sesbania grandiflora* recorded the lowest crude fibre content of 8.43 per cent followed by , *Ailanthus triphysa* (10.15 %).However, the highest value was observed in *Cocos nucifera* (30 %) followed by *Musa acuminata* (23.78%) and *Mangifera indica* (22.1 %).

4.2.1.4 Ether extract (Crude fat)

Among the ten different tree fodders, highest ether extract (crude fat) content was observed in *Moringa oleifera* (7.39 %) followed by *Manihot esculenta* (6.79 %) and *Gliricidia maculata* (5.44 %).Whereas *Ailanthus triphysa* (2.83 %) and *Cocos nucifera* (2.98 %) recorded the lower crude fat content.

4.2.1.5 Total ash

The result of the analysis revealed that the total ash content of the selected fodder leaf samples varied from 5.27 to 12.78 per cent. The highest ash content was observed in *Moringa oleifera* (12.78%) followed by *Mangifera indica* (10.38 %) and *Manihot esculenta* (9.23 %).The investigation also revealed that the lowest total ash content was in *Ailanthus triphysa* (5.27 %) and *Cocos nucifera* (10.15 %).

4.2.1.6 Nitrogen free extract (NFE)

The present study reported that the highest NFE content was noted in *Ailanthus triphysa* (64.72 %) followed by *Mangifera indica* (54.69 %), whereas the lowest NFE content was observed in *Moringa oleifera* (36.36%) and *Erythrina indica* (37.61 %).

4.2.1.6 Acid detergent fibre (ADF)

Among ten different top feeds, lowest ADF content of 11.10 and 16.97 per cent were noticed in *Sesbania grandiflora* and *Ailanthus triphysa* respectively. However Cocos *nucifera* had higher acid detergent fibre (ADF) content of 48.69 per cent, followed by *Gliricidia maculata* (38.64 %) and *Musa acuminata* (37.72 %).

4.2.1.7 Neutral detergent fibre (NDF)

The present investigation revealed that the neutral detergent fibre (NDF) value of fodder tree leaves varied from 17.34 to 65.32 per cent. The NDF contents in *Musa acuminata* (65.32%) and *Cocos nucifera* (63.09 %) were comparatively higher (65.32 and 63.09 per cent respectively) than the rest of the top feeds.

However the lowest values were noted in *Ailanthus triphysa* (17.34 %) and *Sesbania grandiflora* (17.54).

Table 41a. Proximate composition locally available tree leaves and shrubs commonly fed to livestock (% on DM basis)*

Tree fodder	**DM**	**CP**	**EE (Crude fat)**	**CF**	**Total Ash**	**NFE**
T_1: Agathi (*Sesbania grandiflora*)	38.24	25.24	4.47	8.43	9.20	45.19
T_2: *Erythrina* (*Erythrina indica*)	32.53	22.74	4.27	21.87	8.51	37.61
T_3:Drumstick (*Moringa oleifera*)	27.8	18.94	7.39	15.2	12.78	36.36
T_4:Coconut (*Cocos nucifera*)	66.14	13.71	2.98	30.0	6.59	46.72
T_5:Glyricidia (*Glyricidia maculata*)	22.5	16.08	5.44	19.52	8.34	46.62
T_6:Matti (*Ailanthus triphysa*)	32.6	17.03	2.83	10.15	5.27	64.72
T_7:Subabul (*Leucaena leucocephala*)	36.5	24.42	3.39	19.89	7.23	41.15
T_8:Cassava (*Manihot esculenta*)	48.5	19.74	6.79	14.66	9.23	39.58
T_9:Banana (*Musa acuminata*)	25.8	11.91	5.73	23.78	9.65	46.93
T_{10}:Mango (*Mangifera indica*)	40.12	12.21	3.51	22.1	10.38	54.69

DM: Dry matter, CP: Crude Protein, EE : Ether extracts, NFE: Nitrogen free extract

4.2.2 Mineral status of tree fodders

Farm animals require sufficient quantity of feed and fodder that could effectively meet their demands for energy, fats, proteins, minerals and vitamins. Among these nutrients, minerals play a vital role in maintaining normal growth, development and reproduction. The present study investigated the macro mineral (phosphorus, potassium, calcium, magnesium) andmicro mineral status (iron and zinc) of trees fodders and the results are presented in Table 40.

4.2.2. 1 Phosphorus (P)

The investigation on phosphorus content of selected tree fodders revealed that the highest value was in *Leucaena leucocephala* (0.93%) followed by *Erythrina indica* (0.91 %) and *Manihot esculenta* (0.88 %). However the lowest P status was noticed in *Cocos nucifera* (0.49 %).

4.2.2.2 Potassium (K)

Potassium status of all the top feed were under the range of 1.0 to 2.70 per cent with highest value in *Musa acuminata* (2.70 %) followed by *Moringa oleifera* (2.55 %) and *Sesbania grandiflora* (2.45 %). Among the ten different top feeds, *Mangifera indica* and *Erythrina indica* recorded lower K contents of 1.0 and 1.1 per cent respectively.

4.2.2.3 Calcium (Ca)

The highest Ca content was observed in *Moringa oleifera* (2.75 %) followed by *Leucaena leucocephala* (2.02%).However *Gliricidia maculata* and *Musa acuminata* had the lowest calcium content (1.05 and 1.09 per cent respectively) among the selected top feeds.

4.2.2.4 Magnesium (Mg)

The magnesium content of fodder tree leaves varied from 0.24 per cent to 0.60 percent. Moreover, *Moringa oleifera* and *Cocos nucifera* recorded the highest and the lowest magnesium contents (0.60 and 0.24 per cent respectively).

4.2.2.5 Calcium Magnesium Ratio (Ca/Mg)

The present study revealed that fodder with highest Ca: Mg ratio was found in *Leucaena leucocephala* (5.61) followed by *Cocos nucifera* (5.50). However, *Musa acuminata* showed the lowest Ca: Mg ratio of 2.27.

4.2.2.6 Potassium Calcium Ratio (K/Mg) The study revealed that, among the selected top feeds *Musa acuminata* recorded the highest K : Ca ratio (2.48). The lowest K:Ca ratio was in *Erythrina indica* (0.64).

Table 41b. Crude fiber analysis and mineral status of fodder trees and shrubs (% on DM basis)

Tree fodder	ADF	NDF	P	K	Ca	Mg	Ca/Mg	K/Ca
T_1: Agathi (*Sesbania grandiflora*)	11.10	17.54	0.87	2.45	1.39	0.54	2.57	1.76
T_2: *Erythrina* (*Erythrina indica*)	29.39	49.14	0.91	1.10	1.73	0.48	3.60	0.64
T_3:Drumstick (*Moringa oleifera*)	21.39	34.74	0.78	2.55	2.75	0.60	4.58	0.93
T_4:Coconut (*Cocos nucifera*)	48.69	63.09	0.49	1.45	1.32	0.24	5.50	1.10
T_5:Glyricidia (*Glyricidia maculata*)	38.64	48.7	0.26	1.45	1.05	0.42	2.50	1.38
T_6:Matti (*Ailanthus triphysa*)	16.97	17.34	0.53	1.30	1.32	0.34	3.88	0.98
T_7:Subabul (*Leucaena leucocephala*)	27.65	44.87	0.93	2.15	2.02	0.36	5.61	1.06
T_8:Cassava (*Manihot esculenta*)	22.32	42.13	0.88	2.20	1.53	0.42	3.64	1.44
T_9:Banana (*Musa acuminata*)	37.72	65.32	0.78	2.70	1.09	0.48	2.27	2.48
T_{10}:Mango (*Mangifera indica*)	33.63	39.39	0.62	1.00	1.36	0.54	2.52	0.74

NDF: neutral detergent fiber, ADF: Acid detergent fibre

4.2.2.7 Iron (Fe)

Among the selected fodder trees, the iron (Fe) status varied from 58.11 g kg^{-1} to 222.14 g kg^{-1}. The highest content was found in *Leucaena leucocephala* (222.14 g kg^{-1}) followed by *Musa acuminata* (202.98 g kg^{-1}), *Manihot esculenta* (185.97 g kg^{-1}) and *Mangifera indica* (184.27 g kg^{-1}).However the lowest iron content was noticed in *Moringa oleifera* (58.11 g kg^{-1}).

4.2.2.8 Zinc (Zn)

Present investigation revealed that zinc content of the selected tree leaves varied from 7.64 g kg^{-1} to 40.44 g kg^{-1}.The highest Zn content was observed in *Musa acuminata* (40.44 g kg^{-1}) followed by in *Sesbania grandiflora* (35.34 g kg^{-1}).

Among all the ten different tree leaves, lowest Zn content was noticed in *Ailanthus triphysa* (7.64 g kg^{-1}).

4.2.3 Anti-nutritional factors in tree fodders

The major anti-nutritional factors reported in tree fodders include nitrate, oxalate, mimosine tannin, saponins and sinogen. The consumption of fodder containing anti-nutritional factors above critical limit is fatal, and regular use even below critical limit may reduce the growth and quality of animals. The present investigation mainly focused on the presence of two anti-nutrients in fodder trees and shrubs. *viz*., nitrate and oxalates. The results are furnished in Table 41.

4.2.3.1 Nitrate

The present investigation on nitrate content in ten different fodder leaves revealed that, both *Sesbania grandiflora and Gliricidia maculata* had negligible amounts of nitrate. Remaining tree fodders had nitrate in the range of 0.08 g kg^{-1} to 9.26 g kg^{-1}. *Ailanthus triphysa* had comparatively higher nitrate content of 9.26 g kg^{-1} followed by *Cocos nucifera* (4.46 g kg^{-1}).

4.2.3.2 Oxalate

The study revealed that the oxalate content in the selected fodder ranged from 1.43 per cent to 2.97 per cent. The least oxalate content was observed in *Sesbania grandiflora* (1.43 %) whereas comparatively higher oxalate content of 2.97 per cent was observed in both *Musa acuminata* and *Cocos nucifera.*

Table 41c. Anti-nutritional factors and micro nutrient content of locally available tree fodders and shrubs in southern Kerala

Tree fodder	**Anti-nutritional factors**		**Micro nutrient contents (mg kg^{-1})**			
	Oxalate (% DM basis)	**Nitrate (mg kg^{-1})**	**Fe**	**Mn**	**Zn**	**Cu**
T_1: Agathi (*Sesbania grandiflora*)	1.43	0	76.02	9.1	35.34	15.6
T_2: *Erythrina* (*Erythrina indica*)	2.07	2.49	85.97	8.60	12.64	11.9
T_3:Drumstick (*Moringa oleifera*)	2.35	0.69	58.11	14.6	22.84	12.1
T_4:Coconut (*Cocos nucifera*)	2.97	4.46	126.96	31.9	10.14	9.4
T_5:Glyricidia (*Glyricidia maculata*)	2.13	0	130.09	13.29	15.44	14.7
T_6:Matti (*Ailanthus triphysa*)	2.78	9.26	91.94	23.1	7.64	6.9
T_7:Subabul (*Leucaena leucocephala*)	2.13	3.74	222.14	35.10	18.84	10.1
T_8:Cassava (*Manihot esculenta*)	2.81	0.08	185.97	48.60	31.04	10.3
T_9:Banana (*Musa acuminata*)	2.97	0.21	202.98	71.0	40.44	15.7
T_{10}:Mango (*Mangifera indica*)	2.21	6.44	184.27	46.30	11.54	10.8

5. DISCUSSION

The present experiment entitled 'Performance and carbon sequestration potential of top feeds under varied planting geometry' was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during April 2019 to April 2021 to standardize the optimum plant population for higher green forage yield, quality and carbon sequestration potential and to assess the performance of different plant species as top feeds under sole and intercropping system. The study also envisaged to assess the quality of predominant fodder trees and shrubs of southern Kerala. The results of the experiment presented in the previous chapter are discussed here under.

5.1 EXPERIMENT 1: PERFORMANCE AND CARBON SEQUESTRATION POTENTIAL OF TOP FEEDS UNDER VARIED PLANTING GEOMETRY

5.1.1 Growth attributes

5.1.1.1 Top feeds

The growth attributes of both components of a silvi pastoral system is an important parameter which decides the productivity of the system (Edo *et al.,* 2017). Introduction of tree to a land use system bring about a whole complex of environmental changes affecting not just available light but also air temperature, humidity, soil temperature, soil moisture content, wind movement and pest and disease complexes (Sileshi *et al*., 2007). Further, the tree litter and canopy have been documented to improve the microclimate by enhancing rainfall infiltration, soil structure and microfauna, reducing evapotranspiration and temperature extremes and further increasing relative humidity (Saka *et al.* 1994). These factors might have positively influenced the growth of both species in a silvi pastoral system. In this study, the growth characters *viz.*, number of branches and leaf stem ratio of top feeds at trimonthly interval showed a varied response over two years. The result of the study revealed that cropping system fail to exhibit any significant effect on number of branches of top feeds over first year. However, intercropping top feeds with Bajra Napier hybrid recorded 11 per cent increment in number of branches than sole cropping in the second year. This finding is in agreement with Karthikeyan *et al*. (2018) who noticed that number of branches of *Melia dubia* + Hedge lucerne system was more than sole crop of *Melia dubia*. Similar result of 10 per cent increase in number of branches was noticed by Subbulakshmi *et al.* (2019) when *Jatropha curcas* intercropped with cow pea. Tree-grass agroforestry systems have been reported to have potential benefits of improving crop performance by enhancing soil physical nature, fertility and carbon content which is also attributed to soil and water conservation (Mbow *et al*., 2014; Paudyal, 2003). Moreover, intercropping system will control weeds effectively than sole cropping system (Ahadiyat and Ranamukhaarachchi, 2008). These factors might have attributed to an increased number of branches.

According to Sarvade *et al*. (2014), selection of suitable tree species and intercrops is very significant to reduce negative tree-crop interactions. In the present study, among the three selected tree fodders, agathi performed well in terms of number of branches in both years. The climatic condition of the study area was very much suitable for growing agathi as it grows well under tropical warm humid climatic condition with 22°C to 30°C mean annual temperatures, 2000 mm to 4000 mm annual rainfall and an altitude of 800 m to1000 m (Cook *et al*., 2005). Agathi is also adapted to a wide range of rainfall zones and soil types. It can be grown on heavy clay, alkaline and saline soils and poorly drained soils and poorly fertilized soils (Sreekanth *et al*., 2013). Moreover, nodulation and subsequent nitrogen fixation capacity of agathi might have also helped to restore soil fertility indicating its good soil improvement quality. These features might have attributed to the better performance of agathi.

The study also revealed that number of branches of top feeds did not vary significantly with respect to planting geometry of top feeds in first year, however paired system (G_3) has recorded more average number of branches in the second year and it was found to be on par with G_1 (2 m x 1m). This result is in agreement with the findings of Khimani *et al.* (2004) who observed that at wider spacing, *Jatropa curcas* grow taller with more number of branches. This might be due to the fact that crop requires sufficient space to harness sunlight effectively for better growth and development. Moreover, wider distance between the tree rows allow farmers to undertake various cultural operations like ploughing which contribute towards reduction of runoff and conserving soil moisture under rainfed conditions. Furthermore, in wide spaced crops weed management practices can be carried out easily. In another way, roots of closely spaced plants may overlap each other which in turn affects growth of trees than wider spacing (Loades *et al*., 2010). Better growth of plants under broader spacing may exhibit better vegetative growth due to less plant population density and competition which resulted in more horizontal growth and plant canopy area compared to those under narrow spacing. So the branch bearing capacity increased (Sharanya *et al*., 2018). This result also supports the findings of Sharma *et al.* (2017) who revealed less number of branches in *Melia composita* when grown at a narrow spacing of 3 m x 3 m than 4 m x 4 m. The result is also in line with the findings of Korwar and Pratibha (1999) in African winter horn tree (*Faidherbia albida*).

The interaction between cropping system and top feeds positively influenced with agathi + Bajra Napier hybrid intercropping system (C_2F_1) recording more number of branches in both years and the value was comparable to agathi sole cropping (C_1F_1) in first year. High adaptability of agathi in the study area might have contributed to better performance. Moreover, soil moisture conservation and micro climate improvement by associated grass might have led to more number of branches. This result is consistent with the result of Rivest *et al*. (2010) who noticed more number of branches of poplar tree when it was intercropped with soybean.

As mentioned by Obi (1991), planting geometry is an important agronomic trait which has direct effect on light interception and in turn photosynthesis. In the present study, sole cropping with wider spacing of 2 m x 1 m (C_1G_1) between plants might have helped in more lateral expansion of trees and as result more branches could be noticed than narrow spaced trees (2 m x 0.5 m). However the interaction between cropping system and spacing failed to exhibit any significant effect on number of branches in the second year. Considering the interaction between top feeds and planting geometry, average number of branches was maximum when agathi was grown at 2 m x 1 m spacing (F_1G_1) and it was comparable to ...2 m x 0.5 m spaced agathi (F_1G_2) in first year. However in the second year, agathi with paired system of planting recorded higher value and it was found to be on par with F_1G_1 and F_1G_2. This result is consistent with the results of Prasad *et al*. (2010) who found that subabul with paired system of planting recorded significantly more branches. Furthermore, significant interaction between cropping system, top feeds and planting geometry on number of branches of top feeds was noticed and significantly higher mean value was noticed when agathi was grown as a sole crop with 2 m x 1 m geometry ($C_1F_1G_1$) during first year. However intercropping agathi with paired system ($C_2F_1G_3$) had higher average branch number in the second year and it was found to be on par with $C_2F_1G_2$.

Leaf stem ratio is an important factor determining the selection of diet, quality and forage intake of livestock (Nasrin, 2018). Better performance of top feeds mainly depends on its photosynthetic capacity (Ren *et al*., 2016). The present study revealed that leaf stem ratio of top feeds did not exhibit any significant variation with respect to cropping system in the first year. Similar conclusion was made by Ram and Singh (2003) in maize - legume intercropping system. However the data varied significantly in the second year and intercropping top feeds with Bajra Napier hybrid recorded significantly superior average leaf stem ratio. Advantages of intercropping probably derived from high light use efficiency of above ground part (Lv *et al*., 2014) which in turn might have attributed to an improved photosynthetic rate. Moreover, high rate of photosynthesis will improve leaf density, mesophyll cell surface area, leaf weight and specific leaf thickness (Chabot and Chabot, 1977). In addition, by the introduction of a component crop, there might be an increment in plant height in competition to component crop, which might have caused reduction in stem girth of the plant (Ginwal *et al*., 2019).Hence these features of reduced stem girth and improved leaf weight might have further improved the leaf stem ratio.

Regarding different top feeds, agathi exhibited better performance in terms of mean leaf stem ratio in both first year (0.76) and second year (0.78). Furthermore, drumstick recorded significantly the lowest value (0.62 and 0.67 respectively).This finding however slightly deviates from the study of Patrick *et al.* (2020) who conducted a study on productivity of tree fodders in typical home gardens of central Kerala and found that leaf stem ratio of agathi as 1.09 to drumstick as 0.66. As compared to drumstick, agathi is a leguminous crop which has capacity to fix atmospheric nitrogen and in turn improve soil fertility. Moreover, better adaptability of agathi to the study area might have led to a better canopy and in turn high leaf stem ratio.

Nissen *et al*. (2001) reported growth to be a cumulative result of age, geometry and site quality. Among the three planting geometry, top feeds at 2 m x 1 m (G_1) was significantly superior with respect to leaf stem ratio of top feeds in first year, however, paired system of geometry exhibited better performance in the second year. This result is in conformity with the findings of Mohan *et al.* (2013) who claimed that wider planting geometry recorded higher leaf stem ratio in fodder cowpea. More availability of light, water and nutrients offered by wider spaced trees will result in increased crown size, leaf area, synthesis of carbohydrates and hormonal growth regulators which might have further improved the plant height and leaf stem ratio (Baldwin *et al*., 2000; Zang *et al*., 2013; Thakur *et al*., 2019).

The interaction between cropping system and top feeds failed to exhibit any significant effect on average leaf stem ratio during first year. However, agathi + Bajra Napier hybrid intercropping system (C_2F_1) exhibited significantly higher average value in the second year. This might be due to the fact that the climatic condition of the study area was more suitable for the growth of agathi than other two top feeds and more nutrient uptake was also recorded in agathi. Similar conclusion was made by Mehta *et al.* (2017) in drumstick.

Regarding the effect of interaction between cropping system and planting geometry, leaf stem ratio was significantly superior for sole cropped top feeds at 2 m x 1 m geometry (C_1G_1). In general, crop requires sufficient space to harness adequate natural resources for their normal growth and development. In this result wider spacing of 2 m x 1 m of top feed under sole cropping system recorded more leaf stem ratio. Increasing spacing may reduce the competition for available resources and also it could harness more sunlight through which photosynthetic rate may also improve. This may further add a positive effect on leaf stem ratio. However, top feed with paired system of geometry under intercropping system (C_2G_3) recorded significantly higher value in the second year. Similar result was reported by Prasad *et al* (2010) in subabu l+ cow pea intercropping system. They reported that more spread of canopy towards the open side was noticed in paired system of planting. Higher canopy growth may lead to more leaf stem ratio. Moreover, intercropping with fodder will improve microclimatic condition, improve soil fertility and also conserve water. All these factors would have indirectly improved leaf stem ratio.

Moreover, top feed and planting geometry also exhibited significant interaction with respect to leaf stem ratio and agathi with 2 m x 1 m spacing (F_1G_1) was significantly superior in first year. However, agathi in paired system (F_1G_3) recorded higher value in the second year and it was comparable to F_1G_2 (agathi at 2 m x 0.5 m). The result of the study also revealed that the interaction between cropping system, top feeds and planting geometry was not significant with respect to mean leaf stem ratio of top feeds in the first year. However $C_1F_3G_2$ recorded higher value in the second year and it was on par with $C_1F_1G_1$, $C_1F_2G_2$, $C1F_2G_3$, $C_2F_1G_2$, $C_2F_2G_3$, and $C_2F_3G_2$.

5.1.1.2 ***Bajra Napier hybrid***

The result of the experiment indicated that the average plant height of Bajra Napier hybrid was higher when it was intercropped with *Erythrina* in the first year. However the plant height of erythirina was comparable to agathi in the second year. This might be due to the fact that both *Erythrina* and agathi are nitrogen fixing crops and intercropping Bajra Napier hybrid with those nitrogen fixing crops might have had a beneficial effect on the grass. According to Reddy and Pallad (2016), cultivation of legume with non-leguminous crop will enhance the uptake of nitrogen by the companion crop through partitioning the nitrogen fixed by legumes to the non-nitrogen fixing crops grown in association with them. Similar conclusion was also made by Meena *et al* (2011) who observed significantly higher plant height in *Cenchrus ciliaris* when intercropped with *Stylosanthes*. Moreover, favourable microclimate created by legume crop also compliments the better growth of intercrop (Ginwal *et al.,* 2019). Furthermore, shading by these top feeds might have enhanced the synthesis of auxin and gibberellins, which promoted cell division, cell elongation, apical dominance and inter nodal elongation, which in turn might have increased the plant height (Keuskamp *et al.*, 2010). Similar observations were also made by Anita (2002) in guinea grass varieties, Antony and Thomas (2015) in Bajra Napier hybrid and Thampi (2017) in Bajra Napier hybrid. Hence the increased plant height of Bajra Napier hybrid might be due to these positive effects of both *Erythrina* and agathi. The result also revealed that shortest plant of Bajra Napier hybrid recorded when it was intercropped with drumstick (F_3) in both the years. It could be due to non-leguminous nature of drumstick as compared to other two top feeds, *viz*., *Erythrina* and agathi.

The plant height of Bajra Napier hybrid was significantly influenced by the spacing of top feeds. Nasreen (2018) observed that the plant height of palisade grass increased with narrow spacing when it was intercropped with fodder cowpea and fodder rice bean. Among the three different planting geometry of top feeds, maximum mean plant height of Bajra Napier hybrid was noticed when top feeds were planted at a narrow spacing of 2 m x 0.5 m (G_2) and it was found to be on par with G_1 (2 m x 1 m) during both the years. Under closer spacing of 2 m x 0.5 m, more shade might have imparted to associated grass, which leads to an enhanced synthesis of auxin and gibberellins by the grass and further promote cell division, cell elongation, apical dominance and inter nodal elongation, which in turn increases the plant height (Keuskamp *et al.*, 2010).This result is in line with the finding of Sharu (2016) in palisade grass.

Considering all the six harvests in the first year and second year, paired row system of intercropping recorded significantly the lowest plant height. This result is in conformity with those of Buxton (2001) who reported that stem length of crop gets reduced under open condition than that under shaded condition. Wider spacing will allow more sunlight availability to the intercrop leading to less competition between two crops. Furthermore, the interaction between top feeds and planting geometry failed to exhibit any significant interaction with respect to plant height in both first year and second year. This is in conformity with the result of Subbulakshmi *et al*. (2019).

Leaf stem ratio is an important factor which is helpful to determine the digestibility and palatability of any fodder crop (Ginwal *et al.*, 2019). The data regarding leaf stem ratio of top feeds over two years revealed that the average value was significantly higher when BN hybrid was intercropped with *Erythrina* and the lowest in drumstick + Bajra Naper hybrid plot in both the years. This is because the taller a plant, the higher will be the amount of light energy absorbed by such plant and invariably, higher will rate of photosynthesis and consequently the amount of assimilate produced by the leaves (Sunilkumar *et al*., 2005). Moreover, during the sixth harvest in first year and second, third and sixth harvests in the second year, leaf stem ratio of Bajra Napier hybrid in *Erythrina* and agathi plots were comparable. These results are in accordance with the result of Thomas *et al*. (2021) who noticed that guinea grass intercropped with agathi recorded the highest leaf stem ratio.

Among the three planting geometry, growing top feeds in narrow spacing of 2m x0.5m (G_2) registered significantly higher average leaf stem ratio in first year. However, both G_1 (2 m x 1 m) and G_2 recorded significantly higher leaf stem ratio in the second year. This result is in line with the results of Malami and Samaila (2012) who noticed that closer spaced crop had lower stem girth than that under wider spacing. This phenomenon might be due to closer spacing which might have led to a degree of etiolation. Further lower stem girth will lead to more leaf stem ratio. This result is in line with the results of Raza *et al*. (2019). Moreover, paired row of intercropping recorded significantly the lowest leaf stem ratio in both the years.

Regarding the interaction between top feeds and planting geometry, growing *Erythrina* at a narrow spacing of 2 m x 0.5 m (F_2G_2) recorded maximum leaf stem ratio in both the years and the value was comparable with F_2G_1 in the first year and F_2G_1 and F_1G_1 in the second year. This result is consistent with the observation made by Chauhan and Opena (2013) who suggested that narrowing of row space may lead to an increased leaf area and more number of leaves due to high light interception. Moreover, stem girth was reduced in closer planting (Malami and Samaila 2012). These factors might have attributed to an increased leaf stem ratio. In addition both agathi and *Erythrina* can fix atmospheric nitrogen and could improve soil fertility. This feature may also improve the leaf stem ratio of the associated crop indirectly.

The tiller numbers generally determine the resource use efficiency and productivity of the crop. In this study, average number of tillers was significantly higher when Bajra Napier hybrid was intercropped with *Erythrina* in both the years. Regarding individual harvest data, significant variation was noticed only in third harvest in first year and third and fourth harvests in the second year. Moreover, the tiller number of BN hybrid in *Erythrina* and agathi plots were comparable in fourth harvest. Moreover, BN hybrid intercropped with drumstick recorded significantly the lowest tiller number in both years. In many areas, water availability and soil nutrient deficiencies are the two important environmental factors that limit pasture productivity (McDonald and Whitesides, 2002). In this context, incorporating *Erythrina* and agathi could improve soil fertility through nitrogen fixation capacity of legumes (Liao et *al*., 2007). The transfer of nitrogen from legumes to associated grass can occur through decomposition of their residues (Fujita *et al*., 1992).This might have improved soil fertility and in turn number of tillers of BN hybrid. This result is in conformity with the findings of Mariotti *et al*. (2009) who reported that among different grass-legume mixtures barley-vetch mixture has produced higher number of tillers. In addition to this, poor canopy development of *Erythrina* might have reduced the shading effect for the associated grass and as a result more solar radiation may have reached the intercrop increasing the tiller number. Optimum row spacing is an effective approach to optimize tillering capacity (Kakar *et al.*, 2001).

Regarding spacing, mean number tillers of BN hybrid was higher when top feeds were grown with a narrow spacing of 2 m x 0.5 m in both first and second year. However the value was comparable to 2 m x 1 m spacing in the first year. This is mainly because, narrow spaced crops utilize solar radiation efficiently and more interception of photosynthetically active radiation (PAR) might have improved the tillering capacity of the associated crop. These results are in conformity with the findings of Ali *et al.* (2000) who observed more number of tillers in narrow spaced plants than under wider spacing. Similar result was also noticed by Crusciol *et al*. (2013) when maize was intercropped with palisade grass. The interaction between top feeds and planting geometry did not differ significantly during any of the harvest in the first year. However growing *Erythrina* at a spacing of 2 m x 0.5 m (F_2G_2) registered significantly higher value in the second year.

The data on the tussock diameter of the Bajra Napier hybrid revealed that *Erythrina* - Bajra Napier hybrid intercropping system recorded significantly higher average tussock diameter during both the years. Tussock diameter has a direct relation with number of tillers. In this study, higher number of tillers was noticed when BN hybrid was intercropped with *Erythrina*. This result is in line with the result of Choudhary *et al*. (2012) who noticed that the tussock diameter of guinea grass was significantly superior when it was intercropped with mulberry followed by guinea grass + *Terminalia myriocarpa.*

Among the three planting geometry, cultivation of top feeds at 2 m x 0.5 m (G_1) spacing recorded maximum mean tussock diameter and it was found to be on par with the top feeds grown in 2 m x 1 m planting geometry (G_1). Higher number of tillers and leaf stem ratio in narrow spaced plot might have directly improved the tussock diameter. These results are in agreement with the results of Shankar *et al*. (1976) who reported that tussock diameter of *Cenchrus ciliaris* has improved when it was grown within 2m perimeter of *Prosopis cineraria* and as the distance increased, gradually the tussock diameter of grass also reduced. The data also revealed that F x G interaction was not significant with respect to mean tussock diameter of Bajra Napier hybrid in both first and second years.

5.1.2 Yield attributes

5.1.2.1 Top feeds

Intercropping is a cultivation practice that can contribute to ecological and sustainable intensification in crop production (Jensen *et al*., 2015). The result of the experiment revealed that cropping system had significant effect on total green fodder yield of top feeds over sole cropping. The total yield of the crop is an indication of the effective utilization of resources and how long it could maintain utilization efficiently during the growth period of crop (Nasreen, 2018). In this study it was observed that intercropping top feeds with Bajra Napier hybrid produced significantly more total green fodder yield in both the years. This result is in conformity with the findings of Susheela *et al*. (2015) who observed the highest green fodder yield of subabul when it was intercropped with Bajra Napier hybrid and desmanthus. This increase in yield might be due to several reasons. Tree based intercropping system provide various ecosystem services *viz*., nutrient mineralization, climate regulation and improve air, water and soil quality (Alam *et al*., 2013). Moreover, soil moisture conservation by associated intercrop might have helped to satisfy the physiological requirements of main crop which translated into better growth than the conditions prevailed under sole crop situation, which fail to conserve runoff and resulted in low soil moisture content (Kumar, 2014).

Observation on yield data indicated that total green fodder yield under intercropping was 29.83 per cent more than sole cropping in the first year and 24.75 per cent more in the second year. This result is consistent with the findings of Kumar (2014) who observed that *Stylosanthes* + setaria intercropping system produced 23.92 and 25.68 per cent more green fodder yield over sole planting of setaria and *Stylosanthes*. The higher green fodder yield under intercropping system might be due to better utilization of space, light, nutrients and moisture than sole stand (Ram and Parihar, 2008).

Regarding different top feeds, agathi recorded significantly higher total green fodder yield in first year and second year. This is mainly because agathi is a leguminous fodder tree that is well suited for tropical warm humid climatic condition and it will grow well in a wide range of soils. The result of the study is in line with the result of Thomas *et al*. (2021) who reported significantly higher green fodder yield of agathi when it was intercropped with Rhodes grass. In both the years, *Erythrina* recorded significantly the lowest total green fodder yield and there was a yield reduction in *Erythrina* to the tune of 55.34 per cent and 51.52 per cent respectively than the best treatment. It might be due to poor adaptability of *Erythrina* in the selected area that underlines the importance of selection of ideal crop component in a given area. This study clearly revealed that yield attributing factors like number of branches and leaf stem ratio are comparatively less for *Erythrina* and these factors might have directly reflected on the green fodder yield. Furthermore, gall wasp attack was prevalent in the study area and that also might have added to the poor performance of the crop.

Among the three planting geometry, paired system recorded maximum total green fodder yield in the first year and it was found to be on par with G_2. However, reverse trend was noticed in the second year. This might be due to the reason that performance of the plants might have improved due to increased spacing. Moreover, it might have improved the photosynthetic rate leading to greater green fodder yield. The better availability of various natural resources and effective weed control in wider spacing might have helped the plants to grow to full potential and produce higher yield, than closely spaced plants (Rani *et al*., 2020). Furthermore, forage yield is a function of growth parameters like plant height, number of branches and leaf stem ratio. All these characters were higher for paired system which might have contributed to enhanced green fodder yield of top feeds. These results were in agreement with those of Thomas *et al*. (2021) who observed that intercropping Bajra Napier hybrid (paired row) with fodder cowpea recorded significantly more total green fodder yield followed by Bajra Napier (paired row) + agathi.

Regarding the interaction between cropping system and top feeds, green fodder yield was significantly superior when agathi was intercropped with Bajra Napier hybrid (C_2F_1) over all the harvests in first year and second year (Fig. 4a). The climatic condition in the study area might be better suited for the growth and development of agathi than the other two top feeds *viz*., *Erythrina* and drumstick. Similar conclusion was made by Thomas *et al.* (2021) who reported that intercropping agathi with different grass species provided approximately five times more green fodder yield than sole cropping of agathi. The study also revealed that growing agathi with setaria in 2:2 proportions recorded 79 per cent more green fodder yield than sole cropping of agathi.

Considering the interaction between cropping system and planting geometry, higher total green fodder yield was noticed when top feeds were intercropped at 2 m x 0.5 m spacing (C_2G_2) in both the years and it was found to be on par with C_2G_3 (intercropping top feeds in paired system) in the first year (Fig. 4b). This might be due to the fact that under wider spacing, more space will be available above and below ground level and that reduces the competition for the resources like water, light and nutrient. Similar finding was reported by Chauhan and Dhiman (2007) when poplar tree was intercropped with wheat. Similar trend was also noticed in each individual harvest in first year and second year.

The result also revealed that growing agathi at a narrow spacing of 2 m x 0.5 m (F_1G_2) registered significantly higher total green fodder yield in both years (Fig. 4c). Narrow spacing attributes an improved plant density, which is very critical for achieving maximum yield potential under irrigated condition (Zaman *et al*., 2021). Furthermore, narrow spacing often improves photosynthetic capacity by enhancing the interception of available solar radiation and that further improves the yield (Andrade *et al*., 2002). Regarding the individual harvest data, the green fodder yield of F_1G_2 was comparable to F_1G_3 in first, second and fourth harvests in the first year and second harvest alone in the second year. Considering the interaction between cropping system, top feed and spacing, intercropping agathi at 2 m x 0.5 m ($C_2F_1G_2$) proved to be the best treatment (Fig. 4d). This might be due to the fact that intercropping provides better microclimatic condition for the growth of main crop and among the three top feeds agathi was better suited for the selected area. Furthermore, narrow spacing of 2 m x 0.5 m accommodate more plants per unit area and it is a crucial factor that improved yield. Similar findings were made by

Stacciarini *et al*. (2010) who opined that narrow spacing improved the crop yield in maize due to reduced weed competition and optimized sunlight interception.

Dry fodder yield is a function of green fodder yield and dry matter content. Hence the green fodder yield obtained under different treatments directly supports the dry fodder yield of different treatments in the present study. The results of the study revealed that growing top feeds along with Bajra Napier hybrid (C_2) registered significantly higher dry fodder yield in both years. Intercropping reduce run off, soil and nutrient losses and improves the soil moisture availability. These factors might have favoured better growth and green fodder yield, which ultimately has reflected on dry fodder yield of the associated top feed in the study. Furthermore, there was a total yield increase of 28.88 per cent and 27.07 per cent respectively in first and second year for intercropping as compared to sole cropping. Thomas *et al. (*2021) reported that growing agathi with setaria in 2:2 proportion has recorded 80 per cent more dry fodder yield as compared to sole cropping of agathi. The study is also in agreement with the observations of Raj *et al.* (2016) who reported that among different combinations of silvi pastoral systems, higher dry matter yield was noticed when Bajra Napier hybrid was intercropped with mulberry and calliandra. Similar conclusions were also made by Patel *et al*. (2002) in eucalyptus + cowpea and Gill (2005) in acacia + pulse intercropping systems.

Considering three different top feeds that were grown in subplot, agathi registered significantly higher dry fodder yield in both the years and the yield increase of agathi was to the tune of 54.83 per cent in first year and 51.81 percent in the second year as compared to *Erythrina*, which recorded the lowest dry fodder yield. Moreover, different yield attributing factors like number of branches and leaf stem ratio were significantly higher in agathi as compared to *Erythrina* and drumstick and these factors have a direct influence on dry fodder yield of top feeds. This result is in agreement with the findings of Baba *et al.* (2011) in grass-legume mixture.

Planting geometry is one of the most important considerations to avoid competition and for the effective utilization of resources among the agricultural crops and trees (Mohammed *et al.*, 2018). Maximum yield of a particular crop in a given environment can be obtained by adopting row spacing in which minimum competition among the crops are noticed. This can be achieved with optimum spacing which not only utilizes soil moisture and nutrients more effectively but also avoids excessive competition among the plants. In this study, paired system of planting (G_3) was found to be significantly superior with respect to total dry fodder yield in the first year. However, growing top feeds at 2 m x 0.5 m (G_2) recorded maximum dry fodder yield in the second year and the value was comparable with paired system (G_3). Similar result was reported by Thomas *et al.* (2021), who found that among different grass legume mixtures, Guinea grass (paired row) with agathi recorded significantly more dry fodder yield than guinea grass (paired row) + desmanthus. Considering individual harvest data of the first year, G_3 recorded higher dry fodder yield in first and fourth harvest and in first harvest, it was found to be on par with G_2. Wider spacing of the main crop attributed to better utilization of moisture, fertilizers and nutrients beyond the reach of intercropped grass with additional benefit of easy cultural operations as observed by Nissen *et al.* (2001). Furthermore, wider spaces between the rows might have helped the lateral expansion of top feeds and it also provide enough space for the expansion of roots (Subbulakshmi *et al*., 2019). However in second harvest, G_2 was observed to be higher in dry fodder yield and it was found to be on par with $G_{3.}$ Regarding individual harvest in the second year, G_2 recorded higher dry fodder yield in second and third harvests and it was on par with $G_{3.}$ Reverse trend was noticed in the fourth harvest. This result agrees with the findings of Karigoudar and Angadi, (2005) in field bean and Mohamed *et al.* (2018) in *Hardwickia binata* trees.

The interaction between cropping system and top feeds with respect to total dry fodder yield followed same the trend as green fodder yield. Intercropping agathi with Bajra Napier hybrid (C_2F_1) recorded with significantly higher dry fodder yield in both first year and second year, the increase was to the tune of 64.44 percent and 60.86 per cent respectively in first year and second year as compared to intercropping *Erythrina* (C_2F_1).This could be attributed to the superiority in yield attributing characters like number of branches and leaf stem ratio in agathi than *Erythrina*.

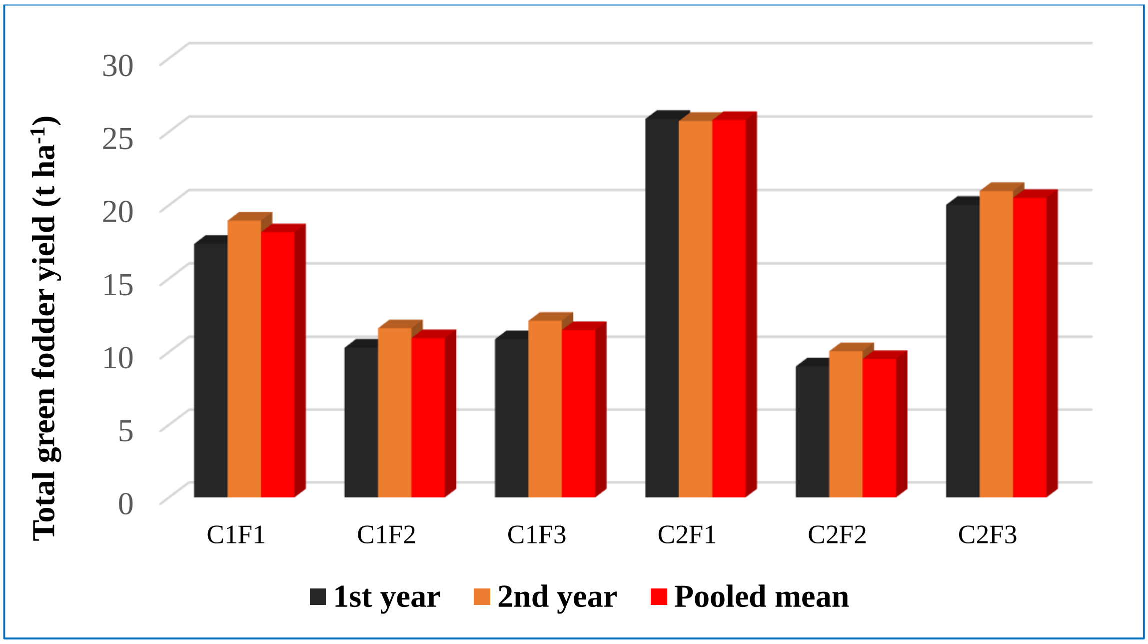


Fig. 4a. Effect of C x F interaction on total green fodder yield of top feeds, t ha^{-1}

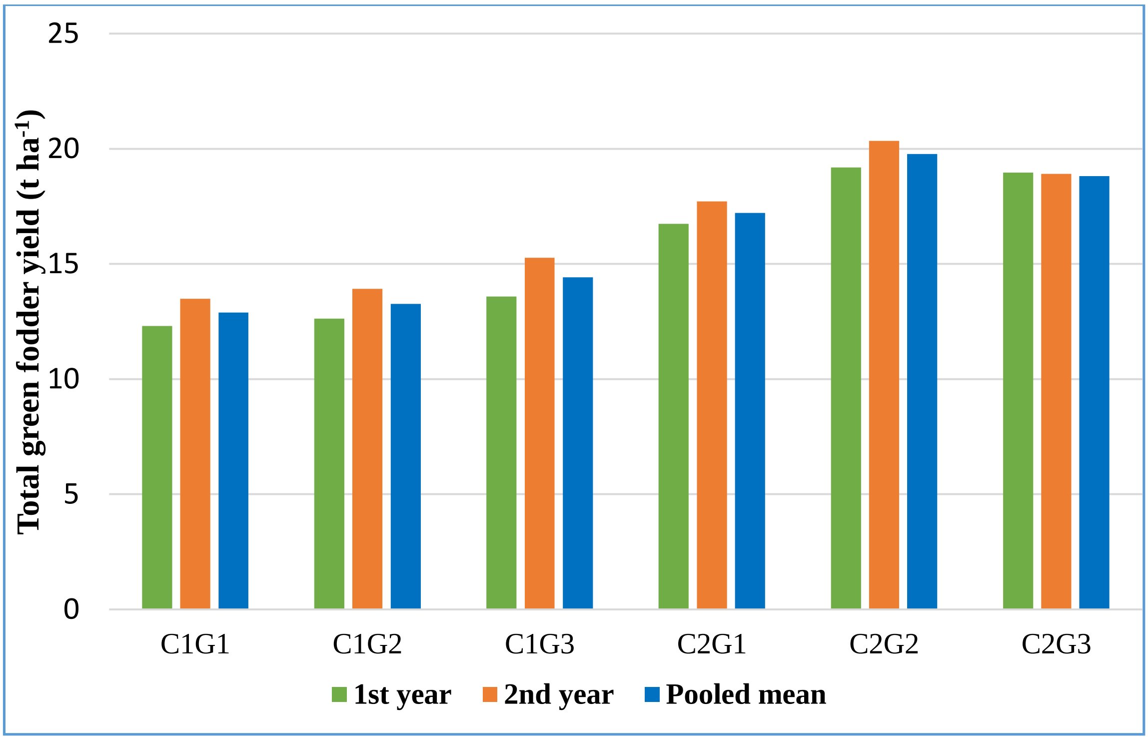


Fig. 4b. Effect of C x G interaction on total green fodder yield of top feeds, t ha^{-1}

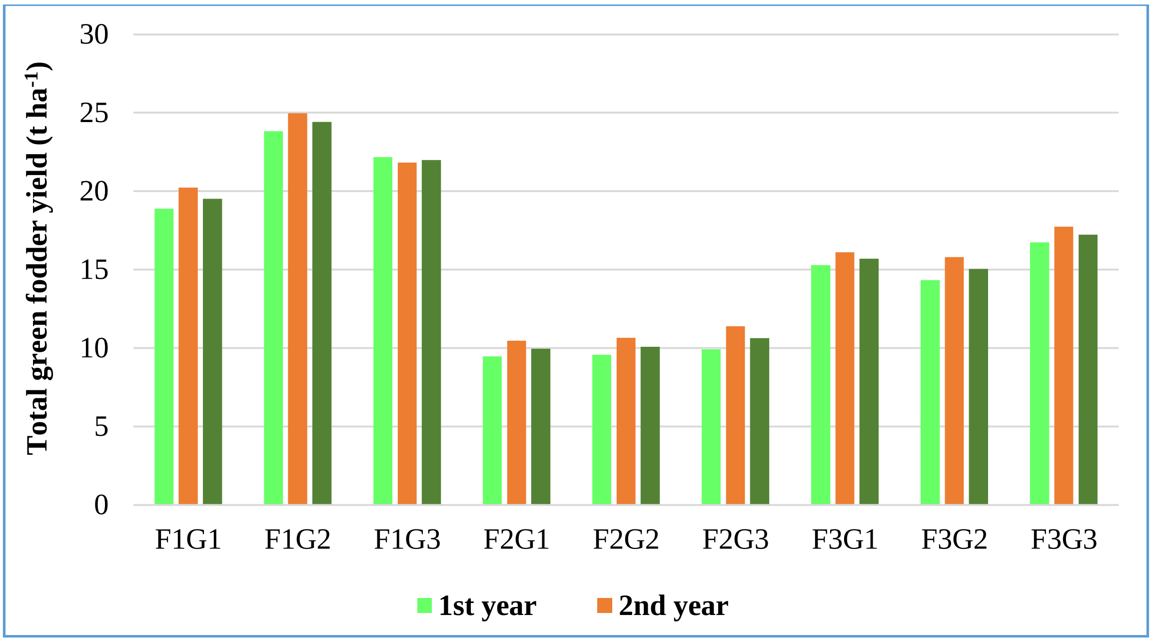


Fig. 4c. Effect of F x G interaction on total green fodder yield of top feeds, t ha^{-1}

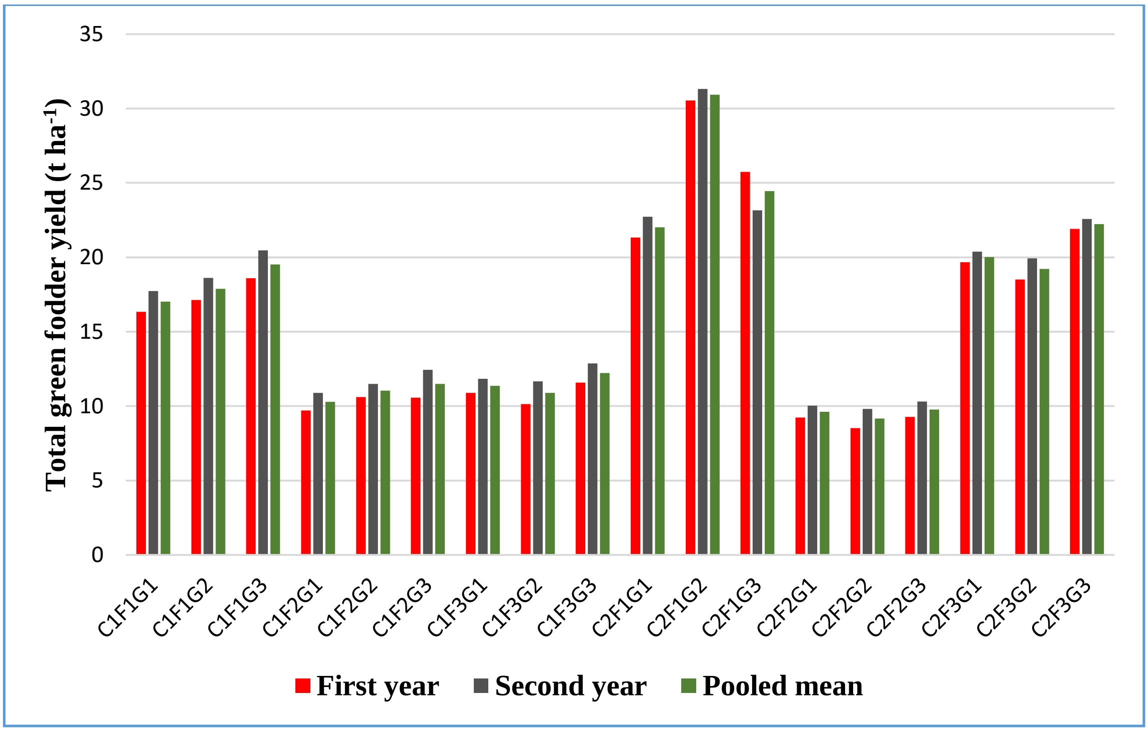


Fig. 4d. Interaction effect of cropping system, top feeds and planting geometry on total green fodder yield of top feeds, t ha^{-1}

Tree spacing influences individual tree growth and in turn tree morphology and dry matter yield. Regarding the interaction between cropping system and planting geometry, maximum total dry fodder yield was noticed by C_2G_2 in both the years and it was comparable with C_2G_3 in the second year. Trees with sufficient growing space show better growth and withstand pest and diseases effectively (Krishna, 2006).With respect to the interaction between top feeds and planting geometry, growing agathi at 2 m x 0.5 m (F_1G_2) was superior with respect to dry fodder yield in both first year and second year. Considering the interaction between cropping system, top feeds and planting geometry, the total dry fodder yield and dry fodder yield of each harvest over two years were significantly superior in $C_2F_1G_2$. These results might be due to the reason that among the three selected top feeds, agathi performed well under the climatic condition of the study area. Furthermore, optimization of sunlight interception at narrow row spacing and increased plant density might have contributed to increased yield.

5.1.2.2 Bajra Napier hybrid

The green fodder yield of Bajra Napier hybrid over six harvests during the first year and second year revealed that intercropping Bajra Napier hybrid with *Erythrina* (F_2) recorded significantly higher values (Fig. 5a). Moreover, there was an increment in total yield of *Erythrina* to the tune of 19 per cent and 20 per cent respectively in the first year and second year as compared to drumstick (F_3), which recorded significantly the lowest values. This reduction in the yield of Bajra Napier hybrid in drumstick plot might be due to the reason that both agathi and *Erythrina* are nitrogen fixing crops which might have improved soil fertility and in turn yield of associated grass. This result is in conformity with the findings of Chauhan *et al.* (2014) who noticed that Bajra Napier hybrid produced significantly more yield when it was intercropped with subabul. Similar observations were also made by Mureithi *et al*. (1995) in subabul + Bajra Napier hybrid and George *et al*. (1996) in coconut + guinea grass. The study also found that all the yield attributing characters like number of tillers, leaf stem ratio and tussock diameter of Bajra Napier hybrid was significantly more when it was intercropped with *Erythrina*. This result might have directly reflected on green fodder yield. The perusal of data also revealed that though both agathi and *Erythrina* are nitrogen fixing crops, the yield of Bajra Napier hybrid in agathi plot declined by 12.62 per cent and 11.91 per cent respectively than Bajra Napier hybrid in *Erythrina* plot. This might be due to the fact that better growth of agathi in the study area might have increased shading effect to the associated grass than *Erythrina*, and under shaded condition, decreased solar radiation would have reduced the photosynthetic productivity and carbohydrate assimilation (Senevirathna *et al.*, 2003) which might have led to yield reduction of grass under shaded situation. This observation is in agreement with the findings of Deepthi (2021) who revealed that the green fodder yield of Bajra Napier hybrid was significantly higher under open condition than different levels of shade. Yield of fodder crops are directly related to light availability and similar results were reported by Antony and Thomas (2015) in different Bajra Napier hybrid varieties.

Regarding different planting geometry of top feeds, significantly higher total green fodder yield of Bajra Napier hybrid was noticed when top feeds were planted at 2 m x 0.5 m spacing (G_2) in both first year and second year (Fig. 5b). Second best treatment was 2 m x 1 m (G_1) planting geometry and there was only around 2 per cent yield reduction in G_1 as compared to the best treatment (G_2) in both the years. Higher green fodder yield of intercrop was contributed by many factors and optimum spacing of associated crop is an important factor which will decrease the interspecific competition for available resources and that will help for better utilization of space, light, nutrients and water. These results are in agreement with the findings of Prasad *et al*. (2010) in eucalyptus + cowpea intercropping system.

Interaction between top feeds and planting geometry was found have positive influence on green fodder yield of Bajra Napier hybrid and the combination F_2G_1 recorded higher total green fodder yield during the first year and it was on par with F_2G_2 (Fig. 5c). However reverse trend was noticed in the second year. This could be attributed to the fact that *Erythrina* is a leguminous fodder crop that fixes atmospheric nitrogen which directly aids the growth of companion grasses.

Moreover, more N could have been fixed by closely planted leguminous crop (G_2) than that of paired system.

The result of the study revealed that the dry fodder yield of Bajra Napier hybrid with respect to different top feeds followed the same trend as that of green fodder yield. Intercropping Bajra Napier hybrid with *Erythrina* recorded significantly higher green fodder yield in all the six harvests during both first year and second year. The data also revealed that there was a total increase in dry fodder yield to the tune of 18.83 per cent and 19.11 per cent respectively in first year and second year as compared to Bajra Napier hybrid intercropped with drumstick, which recorded the lowest green fodder yield. This is in confirmation with the findings of Varsha *et al*. (2019) in mulberry + Bajra Napier intercropping system. The higher dry matter yield of Bajra Napier hybrid in *Erythrina* plot might be due to poor growth and development of *Erythrina* along with nitrogen fixing capacity. Similar findings were also made by Meena *et al.* (2011) when cowpea was intercropped with *Cenchrus setigerus* and Baba *et al.* (2011) in Guinea grass + *Centrosema pubescens* intercropping system.

With respect to sub plot factor, significantly higher total dry fodder yield of Bajra Napier hybrid was noticed when top feeds are grown at 2 m x 0.5 m spacing in both the years. However considering individual harvest data, the value of G_1 and G_2 were comparable in first, second and fifth harvests in the first year and first, second and third harvests in the second year. This might be due to narrow spacing attributes to high plant density which increases the interception of photosynthetically active radiation (PAR) for effective biomass production in associated crop. This result is in conformity with the findings of McKenzie *et al.* (1992) in chick pea.

Moreover, the study also revealed significant interaction between top feeds and planting geometry with respect to total dry fodder yield and the treatment combination F_2G_2 recorded the maximum total dry fodder yield in both first year and second year and the value was comparable with F_2G_1 in the second year (Fig. 5d). This result is in line with the findings of Subbulakshmi *et al*. (2019) when *Jatropha curcas* was intercropped with cow pea.

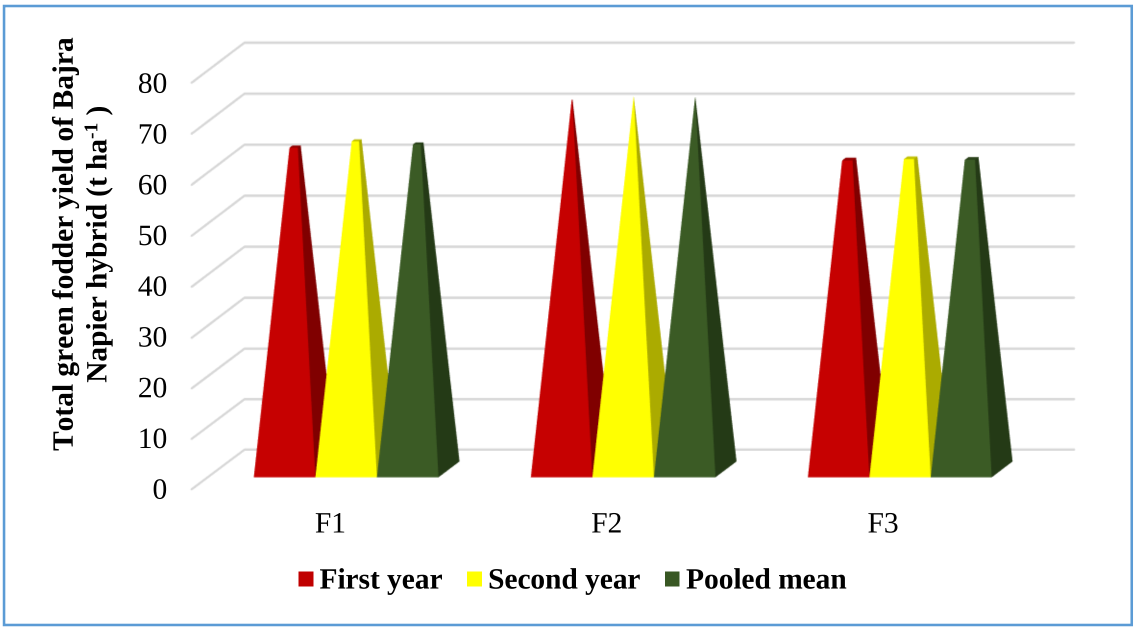


Fig. 5a. Effect of top feeds on total green fodder yield of Bajra Napier hybrid, t ha^{-1}

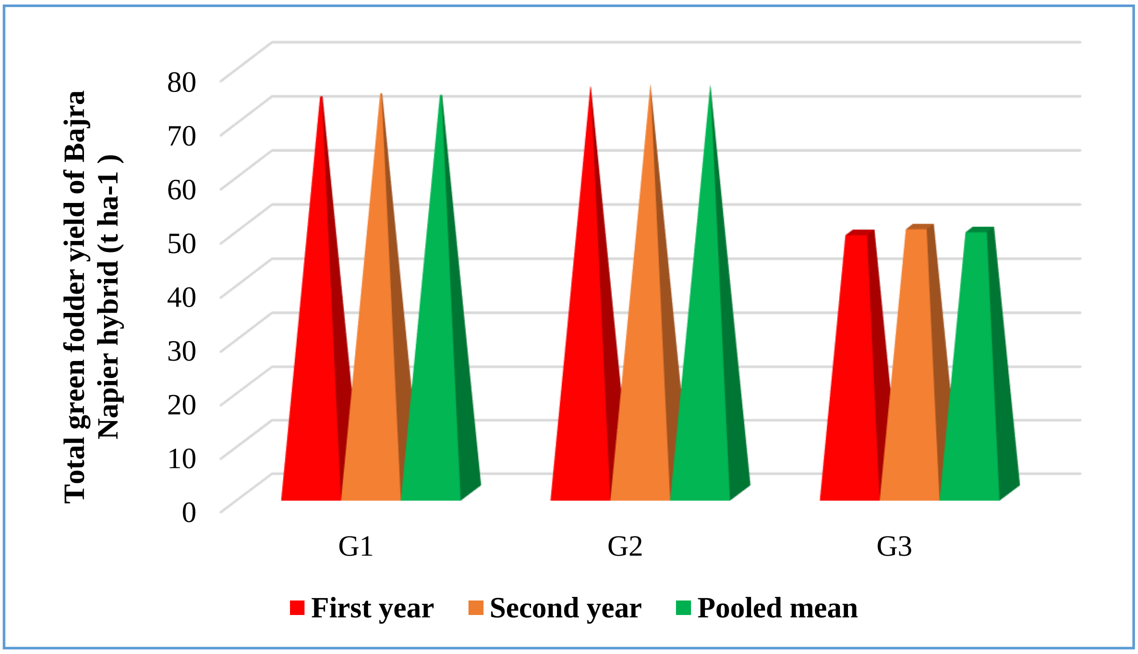


Fig. 5b. Effect of planting geometry on total green fodder yield of Bajra Napier hybrid, t ha^{-1}

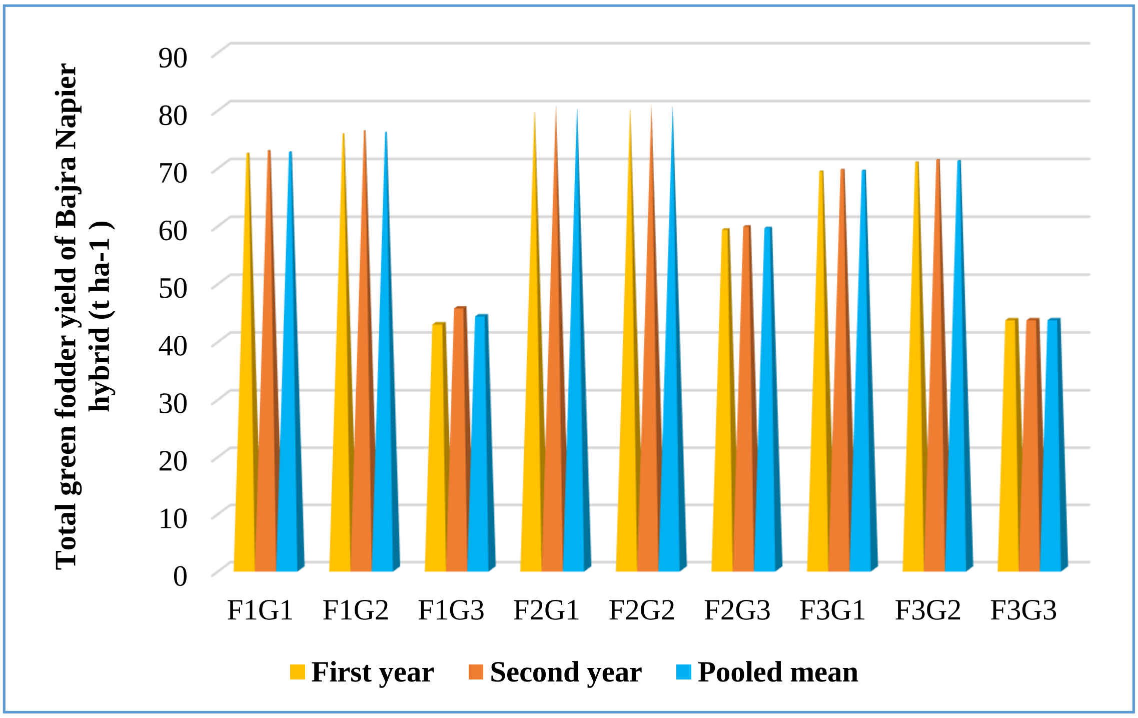


Fig. 5c. Interaction effect of top feeds and planting geometry on total green fodder yield of Bajra Napier hybrid, t ha^{-1}

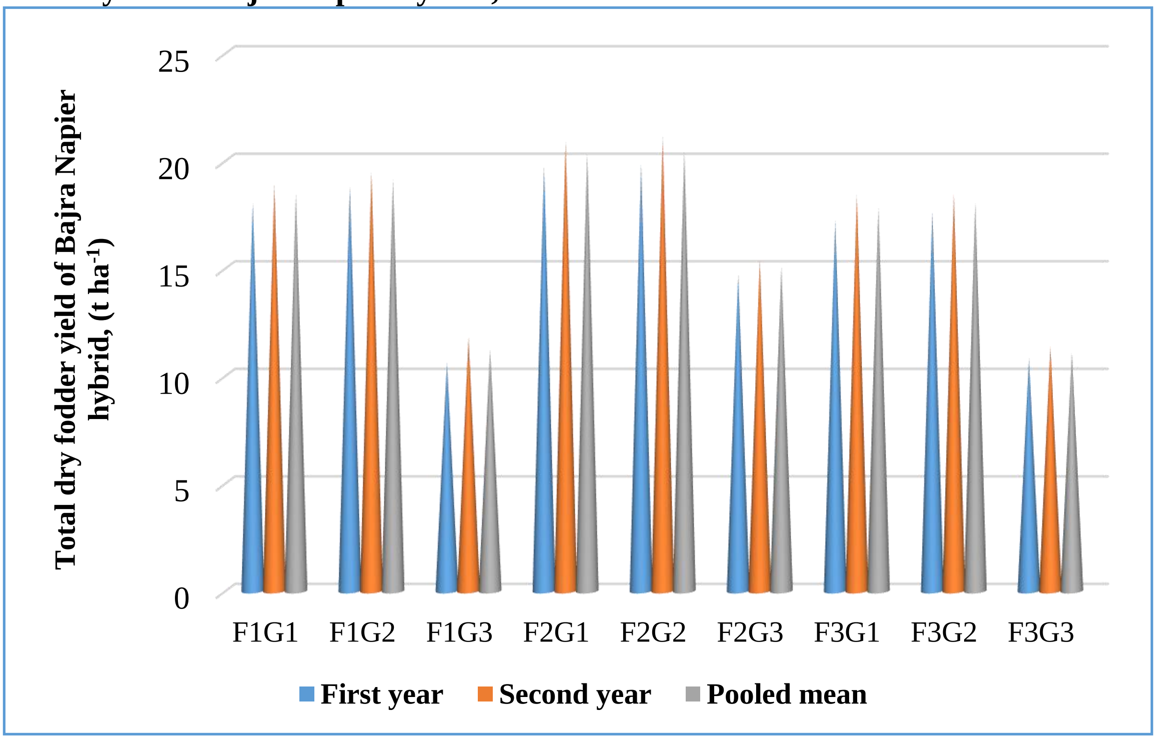


Fig. 5d. Interaction effect of top feeds and planting geometry on total dry fodder yield of Bajra Napier hybrid, t ha^{-1}

5.1.3 Root characteristics

5.1.3.1 Top feeds

The result of the study revealed that root characteristics were significantly influenced by cropping system and intercropping top feed with Bajra Napier hybrid recorded significantly higher root weight and volume (Fig. 6a). Moreover, intercropping recorded 43.78 per cent more root fresh weight and 37.41 per cent more root volume than sole cropping system. This might be due to the fact that the competition for available resources like water is more in intercropping system than sole cropping of top feeds, which might have improved the root biomass in order to take water from deeper layers. Similar finding was also observed by Varsha *et al.* (2019) in Bajra Napier hybrid- mulberry system and Anita (2014) in fodder cowpea-Bajra Napier hybrid system.

Among the three top feeds, the root biomass of agathi was significantly superior. It was also noticed that agathi recorded 82.32 per cent more root fresh weight and 90.12 per cent more root volume than *Erythrina*, which recorded the lowest value (Fig. 6a). This increased root biomass was likely the main cause of the greater success of agathi compared to *Erythrina* and drumstick, in terms of growth and competitive ability. Similar conclusion was made by George (1996) in *Acacia auriculiformis*.

Furthermore, growing top feed in paired geometry resulted in significantly higher root weight and volume. Planting geometry is a factor of crucial importance that determines the extent of competition for below-ground resources. Wider spacing provide lower plant density, which in turn favor better root growth (Farooq *et al*., 2019). Root morphological traits are drastically affected by tree density as root length increased and spread evenly in low density stands due to the large growth space (Stokes *et al*., 2009) and minimal competition for growing space (Mandal *et al*., 2010).This result is in conformity with the findings of Hunter (1997) in *Vitis vinifera*, Bernardo *et al*. (1998) in eucalyptus and Jiang *et al.* (2013) in summer maize.

Significant interaction between cropping system and top feeds was observed in root dry weight and significantly higher dry weight was observed when agathi was intercropped with Bajra Napier hybrid. However, the root fresh weight and root volume were not significant. Similarly, interaction between cropping system and planting geometry failed to exhibit any significant difference with respect to root characteristics. However the interaction between top feeds and planting geometry varied significantly and agathi in paired system recorded higher root weight and volume. In wider geometry, the roots deeply penetrate the soil because of more growth space while in narrow spacing they seem to penetrate into shallow soil surface for the available resources (Van Noordwijk *et al*., 2015). Moreover, wider spacing may provide more area for the expansion of roots as compared to closely spaced plants. This result is in conformity with the finding of Bernardo *et al*. (1998).

Similarly significant interaction between cropping system, top feeds and planting geometry was noticed in root weight and root volume of top feeds after two years (Fig. 6b). Intercropping agathi with Bajra Napier hybrid in paired system of geometry ($C_2F_1G_3$) recorded the highest root weight and volume.

4.1.3.2 Bajra Napier hybrid

Bajra Napier hybrid had high tillering ability, and an extensive rooting system that enabled it to take up nutrients and water from the subsoil and thereby overcome periods of low nutrient and water in the topsoil (Neukirchen *et al*., 1999). In this study, intercropping Bajra Napier hybrid with *Erythrina* recorded significantly higher root fresh weight. This might be due to the reason that lower growth and development of *Erythrina* roots might have provided more area for the growth and development of associated grass, which might have improved the root biomass. Similar findings were reported by Xu *et al*. (2008) in switch grass and sainfoin intercropping system. However root dry weight and root volume failed to exhibit any significant difference.

The present study evidenced that root biomass of Bajra Napier hybrid varied with planting geometry of top feeds. It was noticed that growing Bajra Napier hybrid in 2 m x 1 m geometry of top feed recorded significantly higher root weight and it was found to be on par with paired system. However, the root volume did not vary significantly. This might be due to the fact that as crop grow, competition for below ground resources become more intense in closely spaced crop, thus the roots among individual trees overlap with each other which in turn affects growth of the associated plant. Thus widely spaced trees positively influences the root growth of associated grass. Similar result was reported by Loades *et al*. (2010).

The interaction effect of top feeds and planting geometry was significant with respect to root weight and root volume. The treatment combination F_2G_2 recorded the maximum root weight and volume and it was found to be on par with F_1G_2, F_2G_1 and F_3G_1. Wider spacing might have led to better biomass production which could be attributed to better root structural development coupled with the minimal competition with understorey vegetation and between trees compared to narrow planting. This result is in conformity with the findings of Litton *et al*. (2003) and Chang *et al*. (2012).

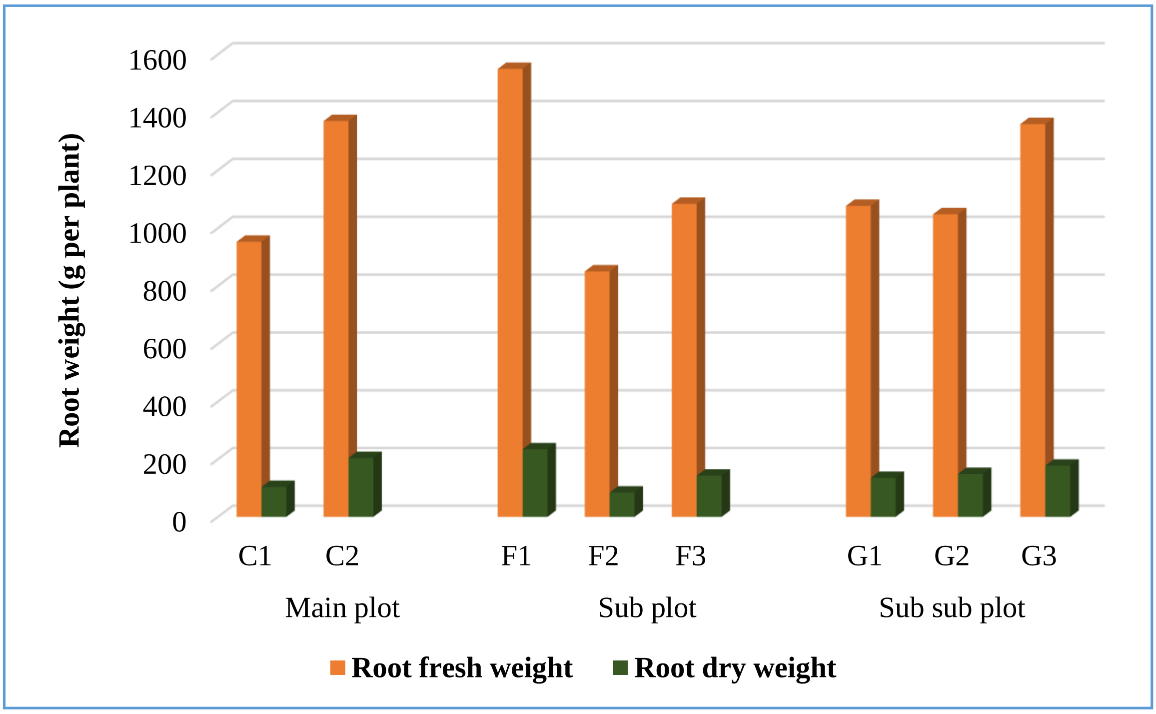


Fig. 6a. Effect of cropping system, top feeds and planting geometry on root fresh weight and dry weight of Bajra Napier hybrid (after two years), g per plant.

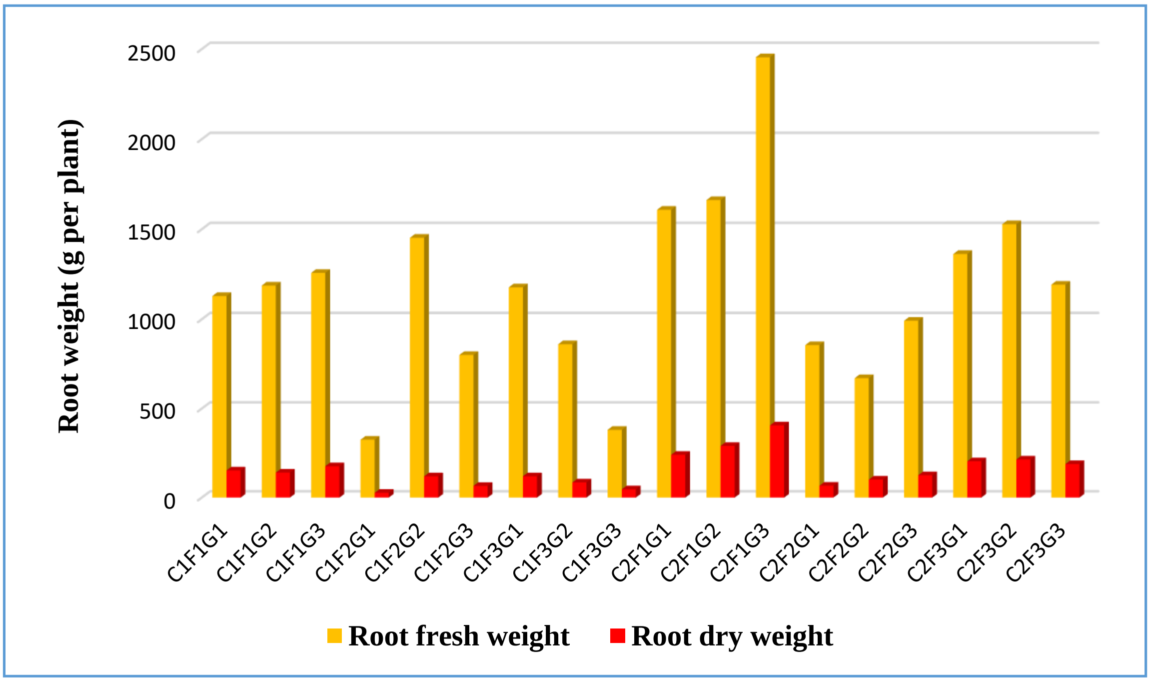


Fig. 6b. Interaction effect of cropping system, top feeds and planting geometry on root fresh weight and dry weight of Bajra Napier hybrid (after two years), g per plant

5.1.4 Physiological parameter

5.1.4.1 Top feeds

Photosynthesis is an important biochemical process that largely depends on the chlorophyll content in plants and quantification of chlorophyll content is a good indicator of growth status of the crop, plant nutrient stress, photosynthesis and growing period (Schlemmer *et al*., 2005). Moreover, light and soil fertility are two factors that directly influence the chlorophyll content. In this study, it was noticed that both cropping system and planting geometry failed to exhibit any significant effect on total chlorophyll content of top feeds. However among the three top feeds, agathi had significantly higher chlorophyll content in both the years. According to Zhang *et al*. (2013), high nitrogen fertilization level enhances the chlorophyll and carotenoid content of the leaves. In this study, uptake of nitrogen, phosphorus and potassium were maximum in agathi as compared to other two top feeds. Since these elements have a direct role in chlorophyll synthesis (Fredeen *et al*., 1990; Zhang *et al*., 2011), it might have improved the chlorophyll content in agathi. This result is in conformity with the finding of Kousar *et al.* (2007) who opined that chlorophyll content of a plant is directly related to the amount of nutrient absorbed by the plant.

Significant interaction between cropping system and top feeds was noticed with respect to total chlorophyll content and growing agathi as sole crop recorded higher value in both the years. However in second year, the value was on par with C_2F_1 (growing agathi in intercropping system) (Fig.7a). This result is in conformity with the findings of Pandey *et al* (2020) who observed higher chlorophyll content in soybean leaves when it was grown as a sole crop and the value was comparable to soybean-maize intercropping system. Furthermore, according to Yang *et al*. (2002), nitrogen application to the crop plant will increase chlorophyll content in crop leaves. In this study, significantly higher nitrogen uptake was noticed in agathi. This might be a reason for increased chlorophyll content.

Ideal planting geometry has prime consideration in the growth and development of crop (De Bruin and Pedersen, 2008). Moreover, ideal row spacing will affect light interception and ventilation of crop canopy (Zhu *et al*., 1998).

The result of the study revealed significant difference with respect to interaction between cropping system and planting geometry in the first year, however it was not significant in the second year. Sole cropping of top feeds in 2 m x 0.5 m (C_1G_2) recorded higher value in first year and it was statistically on par with C_1G_1 (sole cropping top feed in 2 m x 1 m geometry) (Fig.7b). In this study closer spacing of 2 m x 0.5 m might have caused overlapping of adjacent tree canopies and the increased shading might have increased the chlorophyll content than that under wider spacing. This result is in agreement with Yanjun *et al*. (2018). However the interaction effect of top feeds with planting geometry did not vary significantly in both the years.

The result also revealed that interaction between cropping system, top feeds and planting geometry significantly varied only in the second year, and growing *Erythrina* as sole crop at 2 m x 0.5 m ($C_1F_2G_2$) recorded the highest total chlorophyll content and the result was comparable with $C_1F_1G_1$, $C_1F_1G_2$, $C_1F_1G_3$ and $C_2F_1G_1$. This result is in conformity with Sharanya *et al*. (2018).

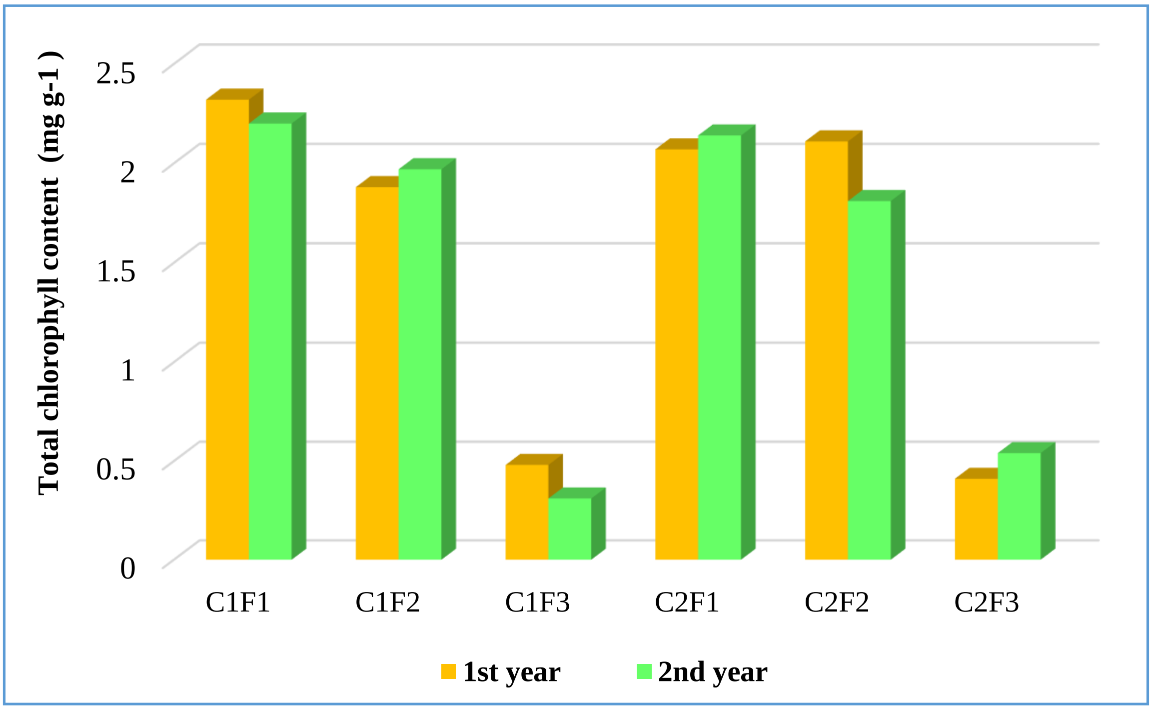


Fig.7a. Effect of C x F interaction on total chlorophyll content of top feeds, mg g^{-1}

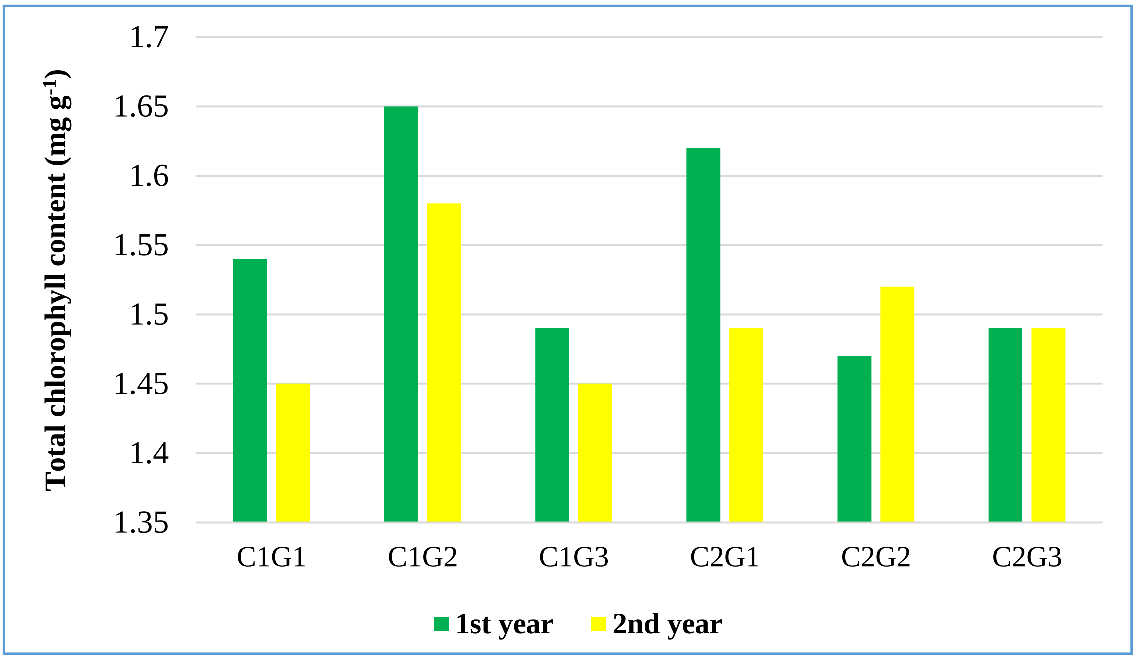


Fig. 7b. Effect of C x G interaction on total chlorophyll content,of top feeds, mg g^{-1}

5.1.4.2 Bajra Napier hybrid

Growing condition and soil fertility are two important factors which have a significant impact on total chlorophyll content of crops. In this study, total chlorophyll content of Bajra Napier hybrid was significantly higher when it was intercropped with agathi in the first year. However the value was comparable with *Erythrina* in the second year. Both agathi and *Erythrina* are leguminous crops which have nitrogen fixation property. Thus they have improved the soil fertility and in turn more nitrogen would have been made available to the associated grass. Moreover, increased soil fertility has a direct role in improving chlorophyll content. This result is in conformity with the findings of Ning *et al*. (2012) in cereal-legume intercropping system. In addition, good canopy structure of agathi might have imparted more shade to the grass and chlorophyll content would have increased with decrease in the intensity of light. This result is in consistent with the findings of Thampi (2017) who observed an increase in chlorophyll content of Bajra Napier hybrid when it was intercropped with coconut and Attridge (1990) reported that plants show adaptive mechanism such as increase in chlorophyll content under shaded conditions to maintain the photosynthetic efficiency.

The study also concluded that chlorophyll content of Bajra Napier hybrid did not vary significantly with respect to planting geometry in first year, however growing top feeds at 2 m x 0.5 m geometry recorded significantly higher chlorophyll content in the second year. Narrow spacing of top feeds might have resulted in more shading effect for the associated grass. This increase in shade might have improved the chlorophyll content. Similar observations were made by Anita (2002) in Guinea grass and Oliveira *et al.* (2013) in tree-grass intercropping system.

Significant interaction between top feeds and planting geometry with respect to total chlorophyll content was observed only in the second year. Growing agathi in 2 m x 0.5 m geometry (F_1G_2) recorded higher chlorophyll content and it was statistically on par with F_1G_2, F_2G_3 and F_3G_1. This might be due to the reason that enhanced nitrogen availability to the grass from associated leguminous crops *viz*., agathi and erythrna and this might have enhanced the translocation of nitrogen from stem to leaves and boosted the synthesis of chlorophyll and thereby improved photosynthesis. This finding is in accordance with the observations of Siddiqui *et al.* (2020). Moreover, from this study it was clear that the agathi had a very good canopy stand as compared to the other two top feeds and thus the grass might have been exposed to more shade. This condition might have enhanced the synthesis of chlorophyll. According to Valladares and Ninemetes (2008), chlorophyll content tend to increase with decreasing light exposure in order to increase light harvesting. This result is also in line with the findings of Chandra *et al.* (2018) in Sesbania.

5.1.5 Quality analysis

5.1.5.1 Top feeds

The crude protein level of forage is an important factor determining its quality. Intercropping system helps farmers to exploit the principle of diversity (Ghosh *et al*., 2004), and also help to avoid reliance on a single crop. In this study it was observed that intercropping tree fodders with Bajra Napier hybrid recorded significantly higher crude protein content than sole cropping in the first year. However cropping system failed to exhibit any significant effect on crude protein content in the second year. Intercropping system generally improve nutrient mineralization and microclimatic condition along with microbial activity. Furthermore, soil moisture conservation by the associated intercrop might have enhanced the uptake of water and nutrients from the soil. All these factors may have directly improved the crude protein content. This result is in accordance with the findings of Susheela *et al*. (2015) who noticed significantly higher crude protein yield when subabul was intercropped with Bajra Napier hybrid as compared to sole cropping system. The above finding is in agreement with Chauhan *et al.* (2014) who reported 55 per cent more crude protein in subabul - Bajra Napier hybrid silvi pastoral model than the sole grass crop.

Among the three top feeds, significantly more crude protein content was noticed in agathi followed by *Erythrina* in both first and second year. Moreover, agathi recorded 30.54 per cent more crude protein than drumstick, which had the lowest value. Increased crude protein content of agathi and *Erythrina* could be related to their nitrogen fixation capacity and enhanced nutrient uptake, especially nitrogen. This result is in conformity with *Strydhorst et al*. (2008) who noticed that legumes tend to improve the quality and nutritional value of mixed forage due to their higher protein content.

Jithendra *et al*. (2013) observed that optimum spacing would help in efficient utilization of solar energy with less competition for growth factors. In this study, among the different planting geometry, the crude protein content was comparable for paired system and 2 m x 0.5 m geometry in the first year. However growing top feeds at 2 m x 0.5 m recorded higher crude protein content in the second year. This result is in consistent with the findings of Ram (2009) who stated that crude protein content of Guinea grass significantly increased in paired row system of intercropping as compared to its sole stand.

The interaction effect of cropping system and top feeds and cropping system and planting geometry did not vary significantly in both first and second years. However significant variation in the interaction between top feed and planting geometry could be observed in the second year. Growing agathi at geometry of 2 m x 0.5 m recorded significantly higher crude protein content in the second year. In this study, it was noticed that nitrogen uptake was higher when top feeds were grown in paired system of geometry. Since nitrogen is the main constituent of all amino acids, it might have contributed to crude protein content. The results were in conformity with the findings of Verma (2012).

Interaction between cropping system, top feeds and planting geometry was significant only in the second year. Growing agathi as sole crop in 2 mx 0.5 m geometry ($C_1F_1G_2$) recorded higher crude protein and it was comparable with intercropping agathi in 2 m x 1 m ($C_2F_1G_1$) and 2 m x 0.5 m geometry ($C_2F_1G_2$). This is mainly due to the nitrogen fixation capacity of agathi along with more N uptake which might have directly improved the crude protein content of the top feed. Moreover, inclusion of protein rich tree fodders such as agathi at higher densities along with grasses has definite advantage in increasing the crude protein content and hence the feeding value of forage which is positively related to milk production (Varsha *et al*., 2019).

The supply of sufficient crude fibre with structural efficiency is important for both ruminants as well as monogastric animals (Dobos *et al*., 2019). In this study, intercropping top feed with Bajra Napier hybrid recorded significantly lower crude fibre content in the second year. However the crude fibre content failed to exhibit any significant difference in the first year. From the results it is clear that legume based intercropping system showed reduced fibre content than sole stand, thus improving the forage quality by decreasing the amount of fibre in plant tissue. Similar conclusion was made by Seresinhe and Pathirana (2000) who observed a reduction in crude fibre content of guinea grass when intercropped with gliricidia. This result is in accordance with the findings of Mpairwe *et al*. (2002) and Abbas (2003) who noticed significantly higher crude fibre content in pure stand as compared to legumes and grass-legume mixture.

Among the three top feeds in sub plot, agathi recorded significantly lower crude fibre content in first year and second year. Furthermore, the crude fibre content did not vary significantly with respect to top feeds in the second year. However, G_1 recorded higher crude fibre content in first year and it was statistically on par with 2 m x 0.5 m geometry. According to Ishiaku *et al*. (2016), crude fibre content was more in wider spaced Columbus grass (*Sorghum almum*) and content increased with advancement in plant spacing and age. This result is in accordance with Olanite *et al*. (2010) .

The interaction between cropping system and spacing did not vary significantly in both years. However, the interaction between cropping system and spacing varied significantly only in the second year. Intercropping top feed at 2 m x 0.5 m (C_2G_2) recorded higher value and it was statistically on par with C_1G_1, C_2G_1 and C_2G_3. Regarding the interaction between top feeds and planting geometry, *Erythrina* in paired system recorded higher crude fibre content in first year and it was statistically on par with *Erythrina* at 2 m x 0.5 m (F_2G_2.). This result is in line with Hassan *et al*. (2014).

Interaction between cropping system, top feeds and planting geometry failed to exhibit any significant influence on crude fibre content of top feeds.

5.1.5.2 Bajra Napier hybrid

The result of the study revealed that intercropping Bajra Napier hybrid with agathi recorded higher crude protein content in both the years and it was eight per cent more than drumstick associated grass in first year and that of 12.2 per cent more in second year. In this study, highest crude protein content was noticed when grass was intercropped with legumes. This might be due to the fact that legume based intercropping system may improve soil fertility, nutrient use efficiency, microbial activity along with better efficiency of resource conversion (Alvey *et al*. 2003; Ghosh *et al*., 2017 and Iqbal *et al.*, 2018). Moreover, legume based intercropping systems also improve the absorption of macro and micronutrients from the soil especially nitrogen, which is essential to produce the necessary protoplasm and amino acids required for the building of plant tissue and plant proteins (Li *et al*. 2003; Crews and Peoples 2004). In this way more nitrogen might have been becomes available to Bajra Napier hybrid intercropped with leguminous tree fodders. Crude protein of forages is reportedly influenced by nitrogen availability and by nitrogen contribution from legumes leading to increased crude protein content of associated intercrops (Ahmad *et al*., 2007). Similar findings were made by Ram and Parihar (2008) in *Stylosanthes* - beard grass intercropping system and Chauhan *et al.* (2014) in subabul + Bajra Napier hybrid inter-cropping system. This result is also in consistent with the findings of Muinga *et al.* (1995) who reported that inclusion of a legume in Napier grass based diet showed an improvement in animal performance in terms of milk production because of their high nutrient contents. Sleugh *et al*. (2000) opined that grass-legumes mixed cropping is an instrumental tool which improve the crude protein content of the associated intercrop.

With respect to planting geometry, significantly higher crude protein content in Bajra Napier hybrid was noticed when top feeds were grown in 2 m x 0.5 m geometry. This is mainly due to more nitrogen uptake under 2 m x 0.5 m geometry which may have directly made an impact on crude protein content of the crop. However the F x G interaction was found to be not significant during both the years.

The crude fibre content of grasses are generally more than that of legumes. In this study, crude fibre content of Bajra Napier hybrid was more than leguminous top feeds *ie.*, agathi and *Erythrina*. The result revealed that crude fibre content of Bajra Napier hybrid did not significantly vary with different top feeds in the second year, whereas highest crude fibre content was observed in Bajra Napier hybrid grown in drumstick plot during first year. According to Abbas (2003) increased nitrogen fertilization may decrease the crude fibre content. This might be the reason for lower crude fibre content in the leguminous crops *ie*., agathi and *Erythrina*. This finding is in agreement with Rekib *et al.* (1987) who observed that growing of grasses and legumes together reduced the crude fibre content of the herbage mixture.

Planting geometry failed to exhibit significant effect on crude fibre content during both the years. Similarly F x G interaction was also found to be not significant. This result is in line with the findings of Sharu (2016) in palisade grass and Velayudham *et al.* (2011) in Bajra Napier hybrid.

5.1.5 Competitive indices

Land equivalent ratio (LER) is the ideal parameter for evaluating the bio suitability of intercropping systems (Mead and Willey, 1980). It represents the relative land area under sole crop to produce same yield as that of intercropping. A unitary value of LER is the reference value. LER value greater than one indicates that intercropping is advantageous over sole cropping in terms of growth and yield of both the species. LER less than one, indicates the negative effect of the interaction on the species in the mixture (Yayeh *et al*., 2014). It is used for determining whether it is more beneficial to go for intercropping than to cultivate them separately. LER is generally used as a single index for expressing the yield advantage. The data on mean LER value of two years revealed that intercropping different top feeds with Bajra Napier hybrid at different planting geometry of top feeds were more than one. This indicated the advantage of top feed-Bajra Napier grass intercropping over sole cropping. The results of the study recorded that intercropping Bajra Napier hybrid with agathi in 2 m x 0.5 m geometry recorded highest LER value of 2.37, followed by Bajra Napier hybrid- drumstick intercropping in 2 m x 1 m geometry (2.35). The results of the study also revealed that drumstick intercropped with Bajra Napier hybrid in paired system of geometry had the lowest LER. Variation in yield advantage with different crop geometry can be explained by the fact that intercropping advantage occurs only when each species has adequate time and space to maximize cooperation and minimize competition between them. Hence, changing the hierarchies and spatial patterns in plant populations may influence the productivity of the intercropping system (Yang *et al*., 2017). Similarly biological suitability due to higher LER (1.45) recorded in subabul-sorghum intercropping system by Palled (1985). Similarly Muhammad *et al*. (2008) and Yadav and Yadav (2001) also reported yield advantage in crop mixtures than equivalent sole crops on the same land area.

The competitive ratio (CR) is an important tool to understand the degree with which one crop competes with the other. Higher CR values for the intercrops indicated that all the intercrops were more competitive than their respective sole crops. The present study revealed that CR value was the highest when agathi was intercropped with Bajra Napier hybrid in paired geometry (3.35) followed by drumstick in 2 m x 1 m geometry (3.05). However intercropping Bajra Napier hybrid with *Erythrina* in 2 m x 0.5 m recorded the lowest CR. These result suggested that among different tree-grass combinations, agathi- Bajra Napier hybrid intercropping system proved to be better competitor as compared to other tree fodders when grown in association with grass. Similar result was also noticed by Tahir *et al*. (2003) in wheat-subabul intercropping system.

Aggresivity measures the aggressiveness of one species towards another in a mixture and their respective land occupancy. The positive value of aggressivity of top feeds is a reflection of more aggressiveness and high competitive ability, whereas negative value of Bajra Napier hybrid indicates its inferior competitive character compared to tree fodders. Greater the numerical value, bigger the difference in competitive abilities and greater the difference between actual and expected yields. The data on aggressivity of different treatment combinations revealed that the highest aggressivity of 1.19 was noticed when drumstick at 2 m x 1 m geometry was intercropped with Bajra Napier hybrid followed by agathi in 2 m x 0.5 m geometry (1.10). The performance of different top feeds in a mixture vary in their ability to extract available resources. Higher aggressivity of drumstick indicated it as a dominant crop and a superior competitor in the fodder tree-grass combination. Thus in a low input system, this intercropping combination can be introduced as an alternative to sole crop of Bajra Napier hybrid grass. More aggressiveness of legumes in grass-legume mixture combination was also reported by Baba *et al*. (2011). The result also revealed that the lowest aggressivity of 0.20 was noticed when *Erythrina* of 2 m x 0.5 m geometry was intercropped with Bajra Napier hybrid. This may be due to the poor performance of *Erythrina* over the other two tree fodders. Moreover, the results of the data further indicated that the component crops did not compete equally. Regardless of the intercropping systems, the positive sign for the main crops (tree fodder) indicated the dominance of top feeds over the intercrops. However negative sign for intercrops indicated that Bajra Napier hybrid were dominated by tree fodders. Similar result was also noticed by Nasreen (2018) in legume-grass intercropping system.

Crowding effect is one of the indices used in computing the competition effect of intercropping. It gives measure of the relative dominance of one species over the other in multiple cropping (Banik *et al*., 2006). Each of the species within an intercropping has its own relative crowding coefficient (RCC) and the one with higher value is said to be more dominant (De Wit, 1960). RCC indicates whether a species of crop, when grown in mixed population produced more or less yield than expected in pure stand. If the component has a coefficient less than, equal to or greater than one, it means that it has produced less yield, the same yield or more yield than expected. It can be inferred that intercropping *Erythrina* with Bajra Napier hybrid was more compatible as the RCC value of both the component crops were more than one, which might be due to better utilization of resources by the component crops. This finding was in line with the findings of Yilmaz *et al*. (2008) who reported that legumes become more competitive than the cereals when planted in equal proportions. The result of the study also revealed that higher RCC value was noticed when *Erythrina* was intercropped with Bajra Napier hybrid in 2 m x 1 m geometry (F_2G_1) followed by F_2G_2. However the lowest value of -0.70 was observed when drumstick was intercropped in paired system. Similar findings were also reported by Innazent *et al*. (2019).

Area time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercropping over sole cropping in terms of variation in time taken by the component crops of different intercropping systems. Among different treatment combinations, highest mean ATER value of 2.37 was observed when agathi was intercropped with Bajra Napier hybrid in 2 m x 0.5 m geometry (F_1G_2) followed by F_3G_1 (2.35). However the lowest mean ATER value of 1.07 was noticed when drumstick was intercropped with Bajra Napier hybrid in paired system (1.07). While calculating LER, the duration of field, dedicated to production is not considered. This was made up by calculating ATER, which consider the land occupancy period of the crop,that is the utilization of area and time by crops in the intercropping system. In this study, land occupancy period of both top feeds and Bajra Napier hybrid were 365 days. This is because both component crops were perennial. Hence it was observed that ATER value was equal to LER value. Higher value of ATER value indicate better combined intercrop yield and temporal difference which existed between the crops. This result is corroborated with the findings of Khan and Khaliq (2004) in cotton- cowpea intercropping system and Awal *et al*. (2007) in barley-peanut intercropping system.

The economic feasibility of intercropping over sole cropping was calculated using the monetary advantage index (MAI). It is an important index in determining economic viability of intercropping. In this study, the least MAI (42166) was obtained in *Erythrina*- Bajra Napier hybrid intercropping system in paired geometry (F_2G_3). Whereas, the highest MAI (15892) was noticed when agathi was intercropped with Bajra Napier hybrid in 2 m x 0.5 m geometry (F_1G_2). These results also support the findings of Ghosh (2004) who found that when the LER and RCC were higher, there was significant economic benefit expressed in terms of higher MAI, indicating that the system is more profitable. The result of the study also showed that MAI, was positive in all the intercropping systems and numerically greater than one. This indicated that the intercropping systems were more economically feasible as compared to sole cropping. Similar results was noticed by Dutta *et al*. (1994) in maize-rape seed combinations. These results followed a similar trend as the LER and ATER. Dhima *et al*. (2007) reported that when LER value was higher, there is economic advantage in terms of MAI. Intercropping lupine-wheat and lupine finger millet also gave more economic returns compared to sole cropping (Yayeh *et al*., 2014).

5.1.6 Nutrient uptake

5.1.6.1 Top feeds

Nutrient uptake and nutrient use efficiency are the two important factors that determines the crop nutrition and it is the biological basis of increase in crop yield (Chowdhury *et al*., 1994). The result of the study revealed that intercropping top feeds with Bajra Napier hybrid recorded significantly higher uptake of nitrogen and potassium by the top feeds during both the years. However cropping system failed to exhibit significant effect on phosphorus uptake. From the study it was also evident that intercropping recorded 13.8 per cent more N uptake during first year and 9.37 per cent more in the second year. Similarly, intercropping also recorded an increased K uptake of 30.20 per cent and 33.38 per cent respectively in first and second years. Higher nutrient uptake of tree-grass intercropping system might be due to higher litter inputs, higher soil moisture levels and lower soil and air temperature due to the associated grass species. This result is in agreement with the findings of Foster *et al*. (2014) who observed higher nutrient content in legume-grass intercropping plots than that in sole cropping system. Similar were the finding of Fan *et al*. (2020) in soybean-maize intercropping system.

Regarding the effect of different top feeds, agathi recorded maximum uptake of N, P and K during first and second year. Moreover, P uptake of agathi was comparable to drumstick in the second year. It was noticed that agathi recorded 114.30 per cent more nitrogen, 80.91 per cent more phosphorus and 81.58 per cent more potassium than that of *Erythrina*, which recorded lowest N, P and K uptake during both the years. Highest P uptake by agathi could be explained by its extensive root system. Since phosphorus is immobile in soil, it will get absorbed only when roots come in contact with organic or inorganic materials containing available forms of the element (Wahua, 1983). In the root study of top feeds, it was clearly revealed that agathi possessed extensive root system than *Erythrina* and drumstick. Hence it could have taken P more effectively than the other top feeds. Similar findings were also made by Zhang *et al*. (2016) in broad bean-maize intercropping system. Moreover, good canopy stand of agathi might have positively influenced the nutrient uptake by reducing solar radiation reaching the soil surface and by lowering the soil temperature (Sennhenn *et al*., 2017).

From the present study it is also evident that similar to cropping system, planting geometry of the top feeds also had significant influence on nutrient uptake. Among the three different planting geometry of top feeds, growing top feeds in 2 m x 0.5 m recorded significantly more nitrogen and potassium uptake during both the years. The same treatment exhibited significantly higher P uptake during second year, whereas it was not significant in the first year. Mushagalusa *et al.* (2008) and Gitari *et al*. (2018) noticed that canopy cover had a key role in controlling nutrient uptake of the crop. In this study, narrowing the top feed spacing might have increased the plant density and canopy cover. According to Sennhenn *et al*. (2017), increased canopy cover could reduce the solar radiation reaching the soil surface which lowers the soil temperature. Moreover, increased canopy cover could also improve nitrogen and phosphorus solubilization and reduce their loss (Gitari *et al*., 2018).These conditions might have improved the nutrient uptake by top feed and grass. Similar conclusion was also made by Jiang *et al*. (2013) in maize.

Regarding the interaction between cropping system and top feeds, agathi intercropped with Bajra Napier hybrid (C_2F_1) recorded significantly higher nitrogen and potassium uptake in both first year and second year. Even though similar treatment combination recorded more phosphorus uptake in the first year, intercropping drumstick with Bajra Napier hybrid (C_2F_3) was superior in the second year and it was on par with C_2F_1 and C_1F_1. This result is in consistent with the findings of Crews and Peoples (2004) who opined that legume based intercropping systems improved the absorption of macro and micronutrients from the soil along with improved nutrient use efficiency. Moreover, agathi is a leguminous crop which might have added more nitrogen in the soil through nitrogen fixation.

Nitrogen uptake by top feeds failed to exhibit significant difference with respect to the interaction between cropping system and planting geometry in the first year. Nevertheless, intercropping top feed in 2 m x 0.5 m geometry (C_2G_2) recorded higher values in the second year and it was found to be on par with C_2G_3 and C_1G_2. Regarding potassium uptake, intercropping top feeds in 2 m x 0.5 m (C_2G_2) geometry recorded higher values. Whereas phosphorus uptake did not vary significantly with respect to cropping system and planting geometry in both the years. In this study, intercropping narrow spaced trees with grass improved nutrient uptake mainly due to higher litter inputs from both tree and grass, effective soil and water conservation, lower soil temperature and higher shading effect. All these features directly or indirectly improved nutrient uptake by the top feeds. Similar finding was also reported by Raza *et al*. (2019) in soybean-maize intercropping system.

The result also revealed that the interaction between top feeds and planting geometry had significant influence on the N uptake of top feeds and growing agathi in 2 m x 0.5 m geometry (F_1G_2) recorded higher uptake in both first and second years. Likewise K uptake has also showed a significant difference and growing agathi in 2 m x 0.5 m geometry (F_1G_2) recorded higher values. However phosphorus uptake failed to differ significantly. This result is in conformity with Pragatheeswaran *et al.* (2021) who observed that significantly higher N,P and K uptake in sunflower when it was grown at narrow spacing of 60 cm x 30 cm than wider spacing of 120 cm x 30 cm. This result is in consistent with the finding of Kumar *et al*. (2011).

The interaction between cropping system, top feed and planting geometry had influence on nitrogen and potassium uptake of top feeds. Intercropping Bajra Napier hybrid with agathi in 2 m x 0.5 m geometry ($C_2F_1G_2$) recorded maximum N and K uptake in first and second years. However N uptake of $C_2F_1G_2$ was comparable to intercropping grass with agathi in paired system of geometry ($C_2F_1G_3$). This was mainly due to narrow spacing with improved canopy stand of agathi which might have decreased the solar radiation reaching the ground. Moreover, extensive root system of agathi would have effectively absorbed water and soil nutrients from deeper layers. All these factors along with nitrogen fixing capacity of agathi might have improved the nutrient uptake from the soil.

5.1.6.2 Bajra Napier hybrid

The result revealed that different top feeds had no significant effect on nitrogen uptake of Bajra Napier hybrid. However growing grass along with *Erythrina* recorded higher phosphorus uptake in the second year. Similarly agathi-grass combination was recorded the highest potassium uptake by grass during both the years and in the second year it was statistically on par when intercropped with *Erythrina*. This is mainly because of the fact that tree component in the tree-grass system might have improved the nutrient availability to the associated grass species. The tree component of an agroforestry system has various advantages like reduction of nutrient losses due to extensive root network (Bergeron *et al*., 2011; Kumar and Jose 2018), increase nutrient content through nitrogen fixation and uplift deep soil nutrients (Pierret *et al*. 2016) and modification of the morphological and chemical processes at the rhizosphere through root plasticity and activity (Munroe *et al*., 2015; Borden *et al*., 2019). These findings are in consistent with the observations of Gulwa *et al*. (2017) who reported that macronutrient concentrations in grasses harvested from the grass-legume mixture plots was significantly higher in comparison to those harvested from the control plots.

Considering different planting geometry of top feeds, uptake of nitrogen, phosphorus and potassium were comparable in 2 m x 0.5 m and 2 m x 1 m planting geometry during first and second years. In the root study of grass, extensive root system of Bajra Napier hybrid was noticed when trees were grown at narrow spacing of 2 m x 0.5 m. Furthermore, closer spacing of trees might have modified the soil microclimate. All these factors might have contributed to increased uptake of nitrogen, phosphorus and potassium.

The result also revealed that F x G interaction effect on nitrogen uptake of Bajra Napier hybrid was not significant. Regarding phosphorus uptake, growing Bajra Napier hybrid along with *Erythrina* in 2 m x 1 m geometry (F_2G_1) recorded maximum P uptake in both the years and it was on par with that of F_1G_2 and F_2G_2.

Interaction between top feeds and planting geometry significantly varied in first year and significantly higher K uptake was noticed when agathi in 2 m x 1 m geometry was intercropped with Bajra Napier hybrid (F_1G_1). However the interaction effect was not significant during second year.

5.1.7 Carbon sequestration potential of the system

Carbon dioxide is one of the major greenhouse gas and its concentration in the atmosphere is believed to be accelerated by human activities such as burning of fossil fuels and deforestation (Solomon *et al*., 2007). In this context, carbon sequestration is an approach by which carbon dioxide can be removed from atmosphere and stored in long lived pools of carbon, which include the above ground biomass, below ground biomass such as roots, soil microorganisms, and the relatively stable forms of organic and inorganic C in soils and deeper subsurface environments (Nair *et al*., 2009). Hence carbon sequestration by the plants paves a way to mitigate the climate change. It has been increasingly recognized that agroforestry practices such as silvi pastoral system has much importance in mitigating climate change effect because of high carbon storage potential (Nair and Nair 2003). The result of the study revealed that intercropping top feeds with Bajra Napier hybrid sequestered more carbon than top feeds when grown as sole crop, which sequestered around 62 per cent less carbon than intercropping system. The findings of Kumar *et al*. (1998) supports this study. They found that average carbon sequestration potential of silvi pastoral system in Kerala was around 6.55 t ha^{-1} yr^{-1}. Another study by Meenakshi *et al*. (2012) observed that Bajra Napier hybrid had higher carbon sequestration capacity than other fodder crops like hedge lucerne, fodder cowpea and fodder maize. Moreover, Kirby and Potvin (2007) reported that carbon sequestration potential of agroforestry system was several times higher than pastures or field crops. Hence incorporating trees along with pastures and crops would result in greater net aboveground and belowground carbon sequestration (Palm *et al*., 2004; Haile *et al*., 2008).

According to Malhi *et al*. (2008), tree component of silvipastural system has an important role in capture and storage of atmospheric CO_2 in soil and vegetation. In this study, among the three fodder trees, the carbon sequestration potential of agathi was significantly higher as compared to other two tree fodders. The results of the study clearly showed that agathi sequestered around five per cent more carbon respectively in the first and second year than *Erythrina* which sequestered less carbon during both the years. According to Nair *et al.* (2009), carbon sequestration by the plants is the function of their dry biomass production and tissue carbon concentration. In this study, it is clearly evident that agathi based silvi pastoral system produced higher dry matter content in terms of foliage yield than other two top feeds due to high suitability of agathi in the study area, which further improved the canopy stand and in turn carbon sequestration. Similar finding was made by Yucesan *et al*. (2019) who observed a linear correlation between canopy density and total carbon stock of the system. This result is in line with the observations of Thomas *et al*. (2021) who found that growing BN hybrid with agathi recorded higher carbon sequestration potential than Bajra Napier hybrid - desmanthus system.

Carbon sequestration potential of the system depends on a number of factors such as land use types, component crop, age of crop, cropping pattern and management practices (Nair *et al*., 2009). Present study revealed that planting geometry had significant role in carbon sequestration potential of the system. Growing top feeds in a narrow spacing of 2 m x 0.5 m (G_2) recorded higher carbon sequestration by the system in first and second year. This result is in line with the findings of Varsha *et al*. (2019), who found that silvi pastoral systems with higher tree densities and high yielding grass species such as Bajra Napier hybrid with good management practice have higher potential to capture atmospheric carbon than traditional silvi pastoral system with widely spaced trees with natural grasses beneath them. This is mainly because of the fact that increased plant density directly relates to total dry matter production, which is a function of carbon sequestration potential of the system.

The interaction between cropping system and top feeds significantly varied with respect to carbon sequestration potential of the system and higher value was recorded in C_2F_1 in both the years (Fig. 8a). However considering the interaction between cropping system and planting geometry, intercropping top feeds with Bajra

Napier hybrid at a narrow spacing of 2 m x 0.5 m (C_2G_2) recorded significantly higher carbon sequestration potential in both the years (Fig. 8b). This study is also supported by the findings of Erkan and Aydin (2016) in *Pinus brutia* plantations. Regarding the interaction between top feeds and planting geometry, growing agathi in 2 m x 0.5 m spacing faired with more carbon sequestration potential (Fig. 8c). Increased plant density along with the fast and vigorous growth of agathi attributed to high dry matter production which further enhanced the carbon sequestration potential of the tree. Similar finding have been reported by Kaul *et al* (2009) and Dhillon *et al*. (2018) who opined that amount of carbon sequestered by a silvi pastoral system is largely dependent on the geometry of perennial component in an agroforestry system and the study evinced that carbon stocks contribution of woody perennials is higher in systems involving closer spacing.

Significant interaction between cropping system, top feeds and planting geometry was noticed in carbon sequestration potential of the system in both the years (Fig. 8d). Intercropping Bajra Napier hybrid with closely planted top feeds ($C_2F_1G_2$) recorded significantly higher carbon sequestration in first and second year. This result is in consistent with the finding of Thomas *et al*. (2021) who revealed that legume-grass mixture with high yielding grass species had higher potential to capture carbon than sole planting. Similar finding was also noticed by Cuartas *et al*. (2014) in subabul based silvi pastoral system and Fang *et al*. (2010) in poplar based intercropping system.

5.1.8 Nutrient status of the soil after the experiment

The result of the study revealed that soil organic carbon content after the experiment failed to exhibit significant difference with respect to cropping system and planting geometry of top feeds. However among the different top feeds highest organic carbon content was noticed in agathi and it was found to be on par with *Erythrina*. Considering the interaction between cropping system and top feeds, intercropping Bajra Napier hybrid with agathi (C_2F_1) recorded higher soil organic carbon content and it was statistically on par with intercropping Bajra Napier hybrid with *Erythrina* and drumstick (C_2F_2 and C_2F_3). According to Singh *et al*. (1997), the organic carbon content of soil is higher for tree based system than crop based systems. Hence higher organic carbon content in agathi+ Bajra Napier hybrid may be ascribed to the large addition of organic matter in the form of litter fall (Moreno *et al*. 2007). Moreover, root study of top feeds also revealed higher root biomass in agathi. This also improve soil organic carbon content along with tree rhizodeposition (Pausch *et al*., 2013).The present study also showed that carbon sequestration potential of agathi was more than other two top feeds. Hence a part of the carbon sequestered might have been stored in the soil pool (Nair *et al*., 2009). Whereas interaction between cropping system and planting geometry and top feed and planting geometry were found to be not significant with respect to organic carbon content. Regarding the interaction between cropping system, top feeds and planting geometry, higher organic carbon was noticed by BN hybrid + agathi in 2 m x 0.5 m planting geometry ($C_2F_1G_2$) and it was found to be on par with $C_1F_2G_1$, $C_1F_3G_2$, $C_1F_3G_2$, $C_1F_3G_3$, $C_1F_1G_2$, $C_2F_2G_3$, $C_2F_3G_1$ and $C_2F_3G_2$. Narrow spacing improve plant density and it may add more organic matter to the soil through litter fall. Further closely spaced plant reduce the solar radiation incidence on the ground, which further lower soil temperature. All these features attributed to increased soil organic matter content (Sreekanth *et al*., 2013).

The results on the chemical analysis of the soil after the experiment revealed that treatments involving cropping system, top feeds and planting geometry failed to exhibit any significant difference with respect to pH and electrical conductivity of the soil after the experiment. Similarly, interactions were also not significant.

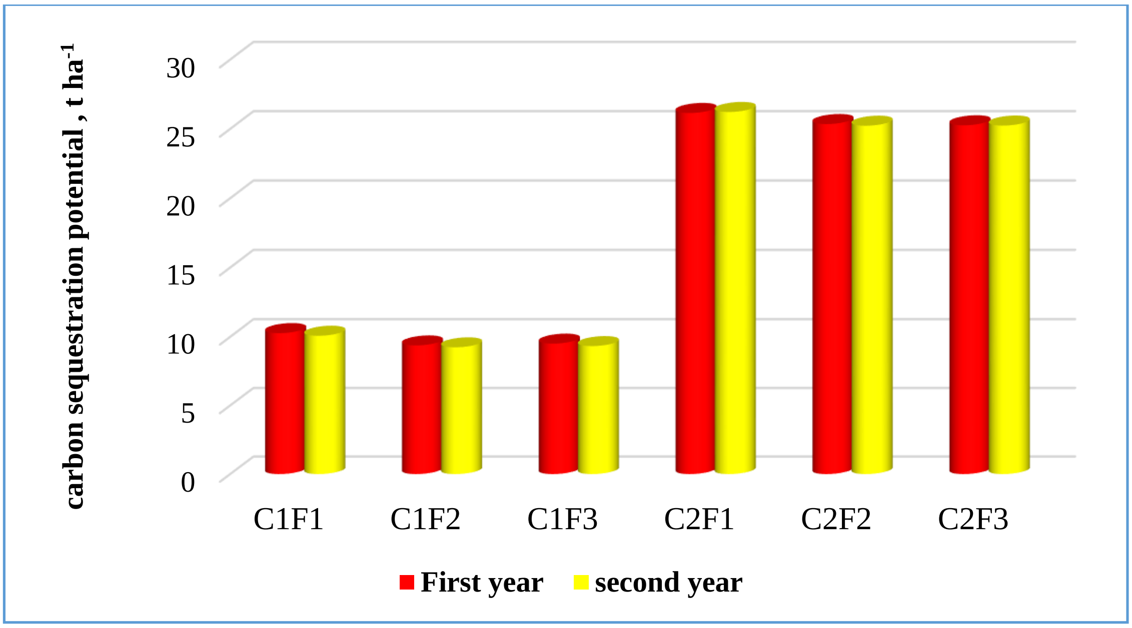


Fig. 8a. Effect of C x F interaction on carbon sequestration potential of the system, t ha^{-1}

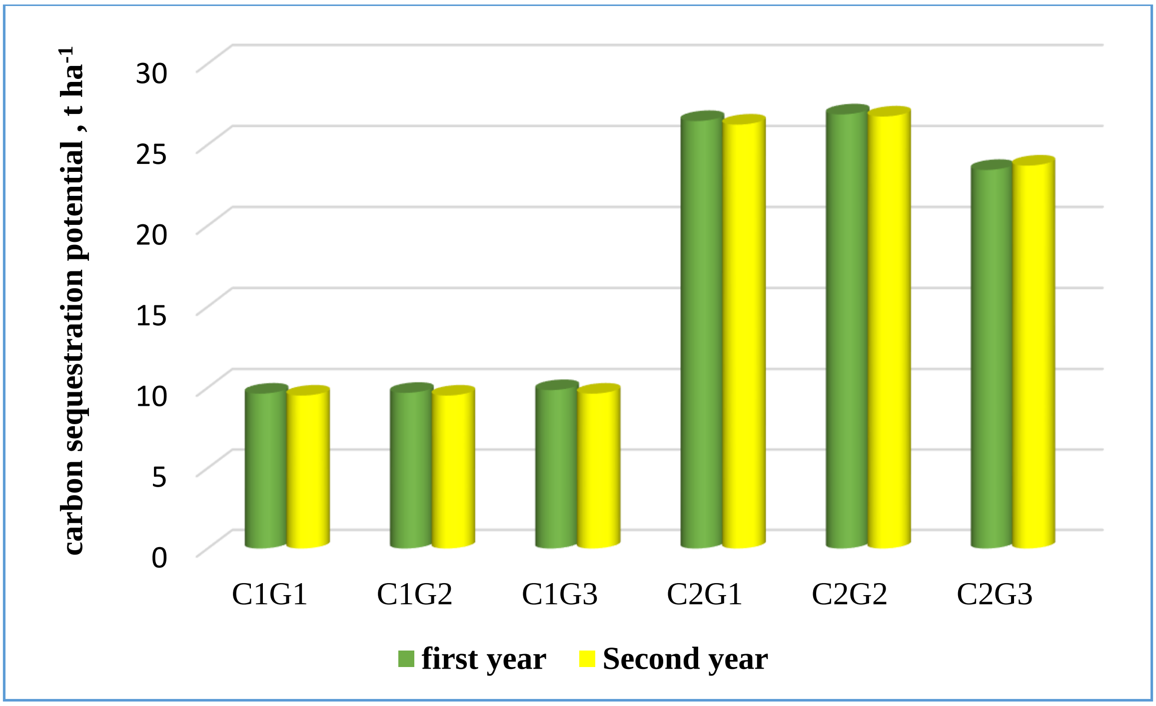


Fig. 8b. Effect of C x G interaction on carbon sequestration potential of the system, t ha^{-1}

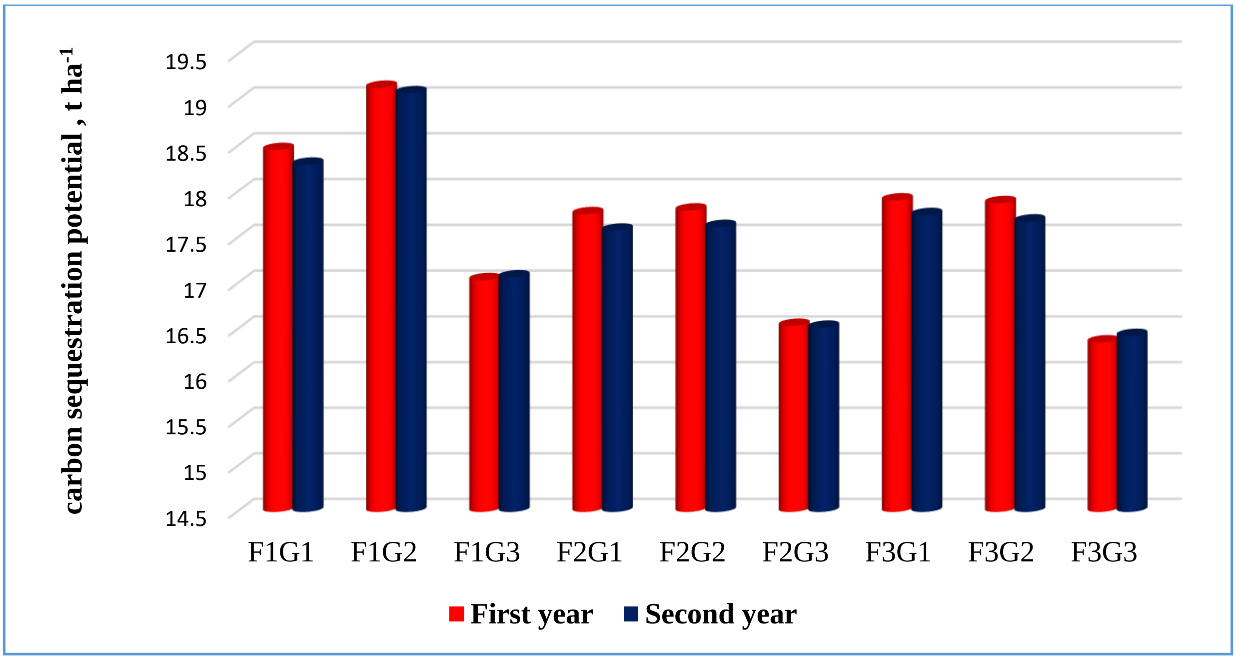


Fig. 8c. Effect of F x G interaction on carbon sequestration potential of the system, t ha^{-1}

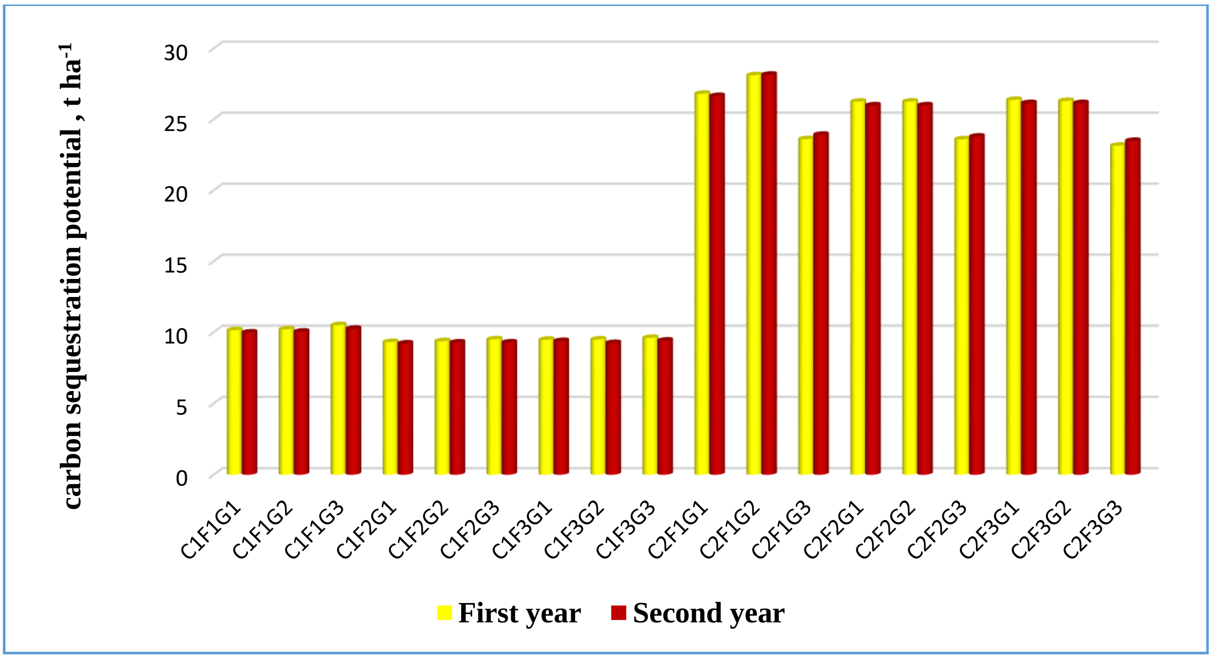


Fig. 8d. Interaction effect of cropping system, top feeds and planting geometry on carbon sequestration potential of the system, t h^{-1}

The available nitrogen content of the soil after the experiment was observed to increase as compared to soil nitrogen content before the experiment. However it was found to be not significant with respect to cropping system, top feeds, planting geometry and the interaction among them. The main reason for the improvement of soil nitrogen after the experiment might be due to the beneficial effect of legumes in contributing nitrogen to the soil through atmospheric nitrogen fixation, decay of dead root nodules and mineralization of shed leaves is well documented (Seresinhe *et al.*, 1994).This result is in conformity with the findings of Vliegher and Carlier (2008) who noticed that inclusion of legumes in a pasture increases the levels of nitrate residue in the soil.

However phosphorus and potassium content of the soil after the experiment differed significantly with respect to cropping system. Sole cropping recorded higher value. In this study lower uptake of P and K was noticed in sole cropping system. As a result more nutrients might have been retained in the soil. Among the different top feeds, the plot were *Erythrina* was grown recorded significantly higher P and K content in soil after the experiment. The result can be well explained by the fact that selected study area was not well suited for the growth of *Erythrina*, which recorded lowest forage yield and less uptake of nutrients. Subsequently more nutrients might have been retained in the soil after the experiment. Furthermore, P content in the soil differed significantly with respect to planting geometry and 2 m x 1 m geometry recorded higher value. However K content was not significant.

Regarding the interaction effects between cropping system and planting geometry, cropping system and geometry and top feeds and planting geometry, the available P content was not significant. However K content in soil after the experiment were comparable for C_1G_2 and C_1G_3. This result is in agreement with the findings of Nasreen (2018) who found that narrow spacing having high plant population retained more nutrients in soil after the experiment. Moreover, F_2G_3 showed higher potassium content in soil after the experiment and it was found to be on par with F_3G_2 and F_2G_1. The result of the study also revealed that available N, P and K content in the soil after the experiment failed to vary significantly in response to the interaction between cropping system, top feeds and planting geometry. This result is in conformity with the findings of Montagnini and Nair (2004) who opined that including trees in pasture as it improve the soil nutrient cycling, cut down soil and water runoff, mitigate climate change *via* carbon sequestration and increased ecological connectivity. However the interaction between cropping system, top feeds and planting geometry was found to be not significant with respect to the available potassium content in the soil after the experiment. In this study good crop stand was noticed in agathi as compared to *Erythrina* and drumstick and as a result more nutrient might have been removed by agathi. This is mainly because quick growing trees and grasses may actively withdraw soil nutrient reserves, especially during the early phase of growth (Kumar *et al*., 1998). Hence more nutrient content in soil after experiment was noticed in *Erythrina* and drumstick. This result is in consistent with the findings of Anita (2014) in grass-legume intercropping. Moreover, higher nutrient uptake was noticed in intercropping system, hence more nutrient content in soil after the experiment was noticed in sole cropping system.

5.1.9 Economics

The result of the study revealed that highest economic return in terms of net income and B:C ratio were noticed when Bajra Napier hybrid was intercropped with agathi at 2 m x 0.5 m planting geometry ($C_2F_1G_2$), followed by intercropping Bajra Napier hybrid with agathi in 2 m x 1 m planting geometry ($C_2F_1G_1$) (Fig. 9). The result of the study also revealed that all the intercropped treatments had B: C ratio of more than two indicating better economics of intercropping top feeds with Bajra Napier hybrid. In forage production, profitability has utmost importance and intercropping fodder trees with grass has been proved to improve the economic returns. Similar results were also documented by Place *et al.* (2009) who reported that introduction of fodder trees with grass in small holder farms in African countries like Uganda and Kenya improved the net income of small scale dairy farmers. Moreover, Thomas *et al.* (2016) also concluded that intercropping Bajra Napier hybrid with banana improved net profit. Similarly Susheela *et al*. (2015) also found higher B:C ratio when Bajra Napier hybrid intercropped with subabul and desmanthus. However sole cropping *Erythrina* at 2 m x 1 m geometry ($C_1F_2G_1$)

resulted in the lowest net income and B: C ratio. This might be due to the lower adaptability of *Erythrina* in studied area.

The results of the present study also documented that integration of top feeds with Bajra Napier hybrid had a favourable effect on the overall fodder production. Among the three top feeds, growing agathi was more economical in the study area. This can be explained by the better climatic adaptation of agathi along with lesser incidence of pests and diseases. However *Erythrina* in the experimental area was heavily attacked by gall wasp, which in turn drastically reduced the foliage yield. Planting geometry is another important factor that determined the economics of the system. In this study narrow spacing of 2 m x 0.5 m recorded higher green and dry fodder yield, which in turn increased the net return and B: C ratio. Higher foliage yield of narrow spaced crop might have directly improved the economic return from the system. This finding is in consistent with the observations of Thakur *et al*. (2015) and Keerthi *et al*. (2015).

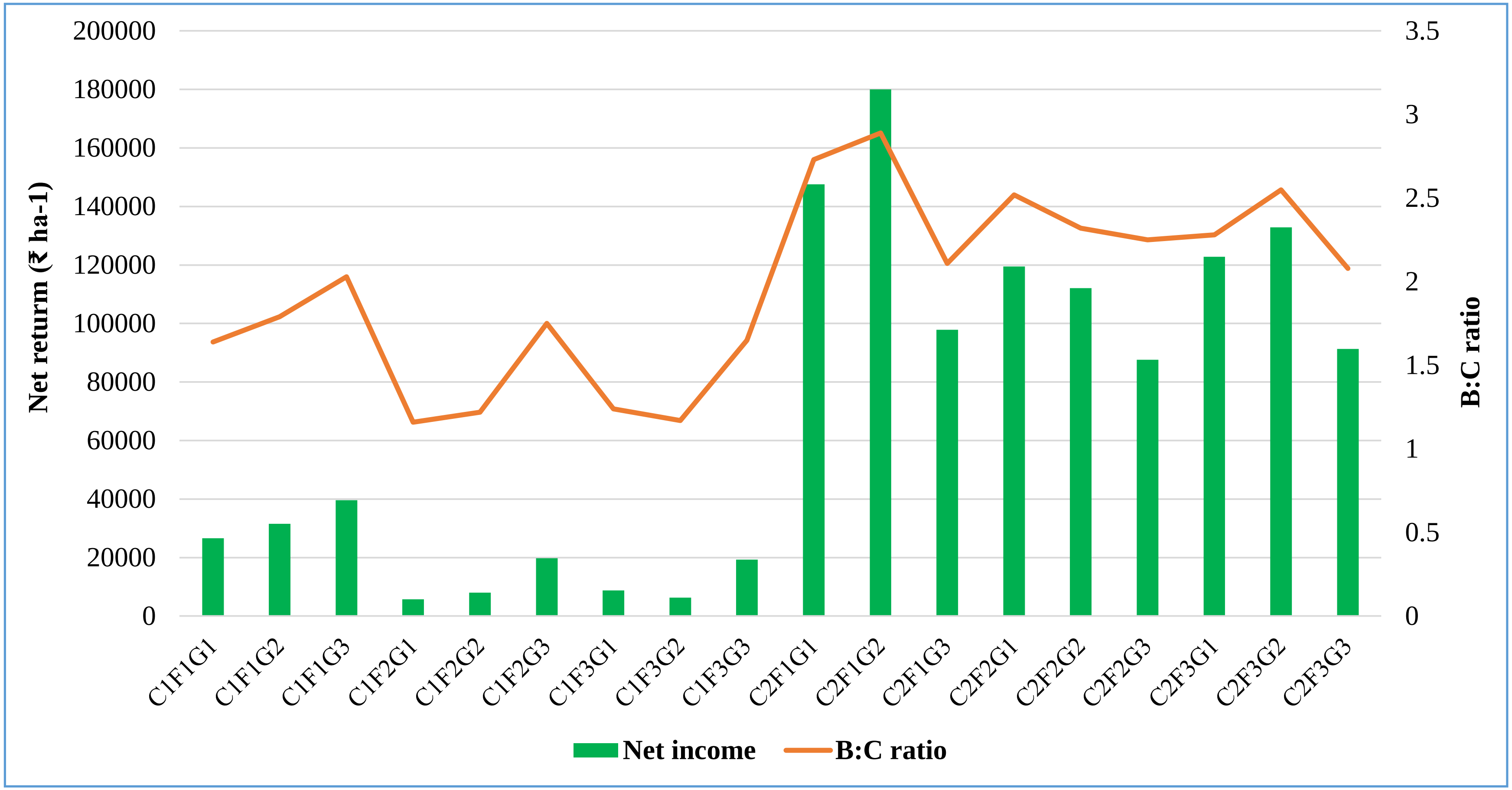


Fig. 9. Effect of cropping system, top feeds and planting geometry on net returns (₹ ha^{-1}) and B: C ratio of the system

5.2 EXPERIMENT II: QUALITY ASSESSMENT OF PREDOMINANT FODDER TREES AND SHRUBS OF SOUTHERN KERALA FOR FEED QUALITY

5.2.1 Proximate analysis of tree fodders

Proximate composition and fibre fraction analysis are two important factors that determine the quality of fodder trees and shrubs. The proximate composition of different tree fodder leaves are indicated in Fig. 10.

The results of the study indicated that the dry matter content of selected tree fodders varied from 22.5 per cent (*Glyricidia maculata*) to 66.14 per cent (*Cocos nucifera*). The Crude Protein (CP) content of fodder tree leaves varied from 11.91-25.24 per cent. The highest CP was observed for *Sesbania grandiflora* (25.24%) followed by *Leucaena leucocephala* (24.42%) and *Musa acuminata* recorded the lowest value (11.91%).These results were in line with the findings of Gaikwad *et al.* (2017). The variation in CP among different tree leaves may be due to differential protein accumulation in the leaves during different stages of the growth of leaves. Similar results were noticed by Chandra and Mali (2014) and Cheema *et al.* (2014).

Alam and Djajanigra (1994) opined that a feed with less than 10 per cent CP may adversely affect the rumen degradation. However, in the present study, CP value of all tree leaves were found to be more than 10 per cent and it indicated that these leaves are potential source of protein and can be used as a good protein supplement to cattle by substituting costly concentrate protein supplying feed stuff like groundnut oil cake, gingelly oil cake and alike (Chithra, 2018).

Among the ten selected tree fodders, highest crude fat (ether extract) content was observed in *Drumstick oleifera* (7.39%) followed by *Manihot esculenta* (6.79%). However the lowest value was noticed in *Ailanthus triphysa* (2.83%) and *Cocos nucifera* (2.98%). These results were in agreement with the findings of Gunasekaran *et al.* (2017). Furthermore,crude fiber content in the sample varied from 8.43 to 30 per cent. The lowest crude fibre content was in *Sesbania grandiflora* and the highest value was observed in *Cocos nucifera* (30%). Since high CP and low fibre content make the best feed for cattle**,** in this study it was revealed that *Sesbania grandiflora* (agathi) is nutritionally superior to other tree fodders with high CP (25.24%) and lower CF (8.43%) content**.**

Present study showed that the total ash content of the selected fodder leaf sample varied from 5.27 to 12.78 per cent, with a mean value of 8.72±0.66 per cent. The highest ash content was observed in *Moringa oleifera* (12.78%) followed by *Mangifera indica* (10.38%) and *Manihot esculenta* (9.23%). The Nitrogen Free Extract (NFE) of the sample determines the soluble carbohydrates and other digestible and easily utilizable non-nitrogenous substances in the feed. In this study, it was noticed that mean NFE content of sample varied as 45.96±2.70 per cent. However, highest value was noted in *Ailanthus triphysa* (64.72%) and the lowest for *Moringa oleifera (*36.36%). The results on the chemical composition top feeds leaves revealed that the values obtained in the present study are in general agreement with those reported by other workers in this regard (Reid and Thomas, 1973; Gomez and Valdivieso, 1985; Ally and Kunjikutty, 2000).

Ruminants such as cattle, goat and sheep have a specialised digestive system in which the stomach is compartmentalized into four sections, which enables them to regurgitate their cud. The CF analysis is a good indicator for predicting nutritional worth of fibrous feed resources, because the intake and digestibility of forages is largely influenced by the fibre content especially Neutral Detergent Fibre (NDF) and Acid Detergent Fiber (ADF) (Harper and McNeill, 2015). NDF value is a good indicator of the bulkiness of forage and can be used to calculate the amount of forage intake by the animal. Increase in NDF value generally decreases the dry matter intake by the animals. Whereas ADF content of fodder leaves indicates the potential production of energy. High ADF content in a feed indicates a reduced energy, *i.e*., reduced quality (Chithra, 2018).

The present study therefore revealed that the NDF value of fodder tree leaves varied from 17.34 to 65.32 per cent (Table 18). The highest NDF value was observed in *Musa acuminata* (65.32%) followed by *Cocos nucifera* (63.09%) and *Erythrina indica* (49.14%). The lowest value was noticed in *Ailanthus triphysa*

(17.34%). Fodder with low NDF content generally has higher ruminant feed intakes, higher production performance and rumen health, thus low NDF value is desired (Harper and McNeill, 2015). The present study also showed that Cocos *nucifera* has higher ADF content of 48.69 per cent, followed by *Musa acuminata* (37.72%). Whereas the lowest content of ADF was observed in *Sesbania grandiflora* (11.10%).Since ADF values are inversely related to digestibility, forages with low ADF concentrations are usually higher in energy (Chali *et al*.,2018).

5.2.2 Mineral status of tree fodders

Minerals play a dynamic role in normal growth, reproduction and proper functioning of the animal's body including protection and maintenance of the structural components of the body, organs, tissues and also as constituents of body fluids. Low quality forages contain reduced amount of macro and micro minerals and thus their utilization could adversely affect rumen microbial growth and activity, leading to lowered feed digestibility (Kumar and Soni, 2014). Minerals have an indispensable role in the metabolism of enzymes, hormones and vitamins. Moreover,macro nutrients like calcium (Ca) and phosphorus (P) works conjointly and have important role in bone development. Apart from this, Ca has a crucial role in muscle function whereas P regulates the metabolic function throughout the body. Magnesium has an inevitable role in nervous system function and carbohydrate metabolism and potassium regulates osmotic pressure and transport nutrients in and out of cells.

The mineral status of feeds and fodder mainly depends upon the cropping pattern, soil type, rainfall and feeding system of that particular region of the country (Bhanderi *et al.*, 2014). In India, these above mentioned parameters also vary with different agro-climatic zones. Thus, deficiency and surplus of a particular mineral is area specific (Garg *et al*., 2005).The macro mineral status (P, K, Ca and Mg) of the selected fodder tree leaves are given in the table 18. It was observed that highest phosphorus (P) content was found in *Leucaena leucocephala* (0.93%) followed by *Erythrina indica* (0.91%) and *Manihot esculenta* (0.88%) (Fig.11).Whereas the lowest P status was found in *Cocos nucifera* (0.49%). Potassium status of all the top feed come under the range of 1.0 to 2.70 per cent with highest value noticed in *Musa acuminata* (2.70%) followed by *Moringa oleifera* (2.55 %) and *Sesbania grandiflora* (2.45%). However highest Calcium (Ca) and magnesium (Mg) were found in *Moringa oleifera* (2.75% and 0.60% respectively).Higher levels of Mg resulted in a significant decrease in the Ca: Mg ratio and higher levels of Ca, will lower the K:Ca ratio in the plant. Hence, in this study, highest Ca: Mg ratio was found in *Leucaena leucocephala* (5.61) followed by *Cocos nucifera* (5.50). Even though *Musa acuminata* showed lowest Ca : Mg ratio (2.27),but it exhibited highest K:Ca ratio of 2.48. These results were in line with the findings of Bhanderi *et al*., 2014; Mondal *et al*., 2016 and Gaikwad *et al*., 2017.

Fodder trees and shrubs represent an enormous potential source of energy, fats, proteins, minerals and vitamins for livestock. Among these sources, micronutrients play an important role in plant metabolism starting from cell formation, cell wall development, chlorophyll formation, respiration, photosynthesis, enzyme activity and nitrogen fixation. Micronutrients are otherwise known as trace elements as it is required in extremely small quantities to the crops and livestock; however, it does not decrease its importance in cattle health. The deficiency of any of the micronutrient may cause problems in forage quality and health disorders in livestock.

The results of the study showed that the highest Fe content among tree trees was noticed in *Leucaena leucocephala* (222.14 mg kg^{-1}) followed by *Musa acuminata* (202.98 mg kg^{-1}). These results were in general agreement with those reported by Pugalenthi *et al.* (2004) and Fasuyi, (2005). The lowest Fe content was noticed in *Moringa oleifera* (58.11 mg kg^{-1}). This finding was in line with the reports of Singh and Banu (2014), who reported that Fe content in drumstick, comes under three categories *viz*., low, medium and high. Among these three categories, drumstick with low Fe category was observed in India (3 to57 mg kg^{-1}).

Zinc (Zn) plays an active role in various metabolic activities including the synthesis of certain proteins, carbohydrate and chlorophyll. Apart from these functions, the presence of Zn in plant tissue will help to withstand cold temperature and has an essential role in the formation of auxin, which helps in growth regulation and stem elongation. Present study revealed that zinc content of the selected tree leaves varied from 7.64 mg kg^{-1} to 40.44 mg kg^{-1} (Table 19).The highest Zn content was observed in *Musa acuminata* (40.44 mg kg^{-1}) followed by in *Sesbania grandiflora* (35.34 mg kg^{-1}). Among all the ten different tree leaves, lowest Zn content was noticed in *Ailanthus triphysa* (7.64 mg kg^{-1}). However these values seem to be lower as compared to an earlier report in the same crops (Pugalenthi *et al.*, 2004).

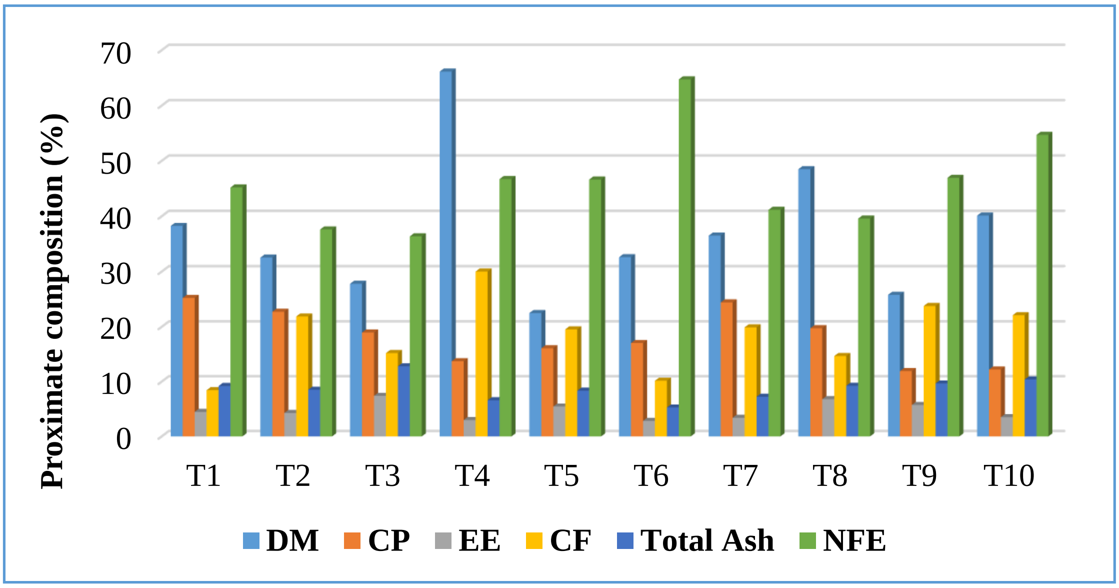


Fig. 10. Proximate composition of predominant fodder crops and shrubs of southern Kerala, per cent

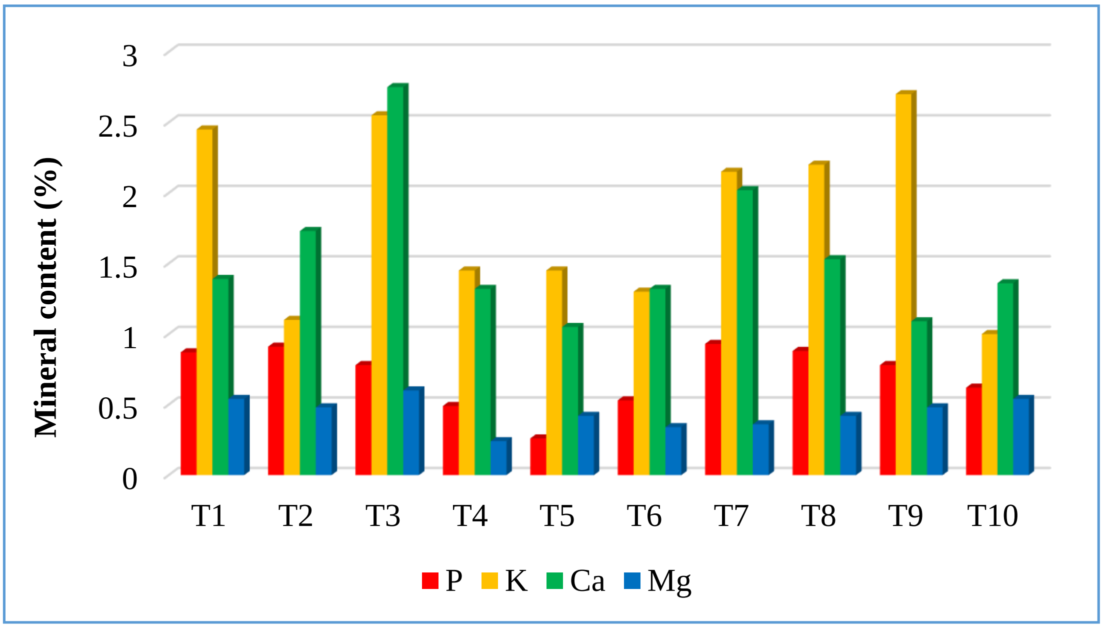


Fig. 11. Mineral content in predominant fodder crops and shrubs of southern Kerala, per cent

5.2.3 Anti-nutritional factors in tree fodders

The utility of the leaves, twigs and pods of trees and shrubs as an animal feed is sometimes limited by the presence of certain substances which are produced in plants by different mechanisms and it adversely affects the optimum nutrition. Such substances are known as anti-nutritional factors. These factors either directly or indirectly interfere with the feed utilization or adversely affect the normal health and development of animals. It may negatively affect the nutrient intake, digestion, absorption and utilization. The major anti-nutritional factors found in plants are nitrate, oxalate, mimosine, tannin, saponins and sinogen. Among these anti nutritional factors, nitrate and oxalate contents in ten different top feeds are analysed in this study.

Nitrogen can be taken up by the plants in the form of nitrate from the soil and transported into the leaves. Under stressed condition, there is a chance of nitrate accumulation in plants. The major nitrate accumulating fodders are sudan grass, pearl millet and oats (Singh *et al*., 2000).Under normal condition, plant nitrate will be converted into amino acid and protein, but higher accumulation of nitrates in animal body may lead to direct absorption through rumen wall to the blood streams, which converts the haemoglobin in the blood to methamoglobin. This compound methamoglobin cannot carry oxygen and thus blood turns to chocolate brown colour (Kumar *et al*., 2017).Nitrate poisoning is more prevalently found in sheep and cattle (Neale, 2006).

Among selected fodder trees, it was observed that both *Sesbania grandiflora and Gliricidia maculata* had negligible amount of nitrate. Remaining all tree fodders have nitrate ranging from 0.08 mg kg^{-1} (*Manihot esculenta*) to 9.26 mg kg^{-1} (*Ailanthus triphysa*) with an average of 2.72±1.02mg kg^{-1}. The nitrate content in fodder at a range of 0-1000mg $kg^{-1}$is considered as safe to feed cattle under all conditions (Andrae, 2008). The present study was in agreement with the findings of Kumar *et al*. (2017), where he observed that the nitrate accumulation is more likely to be found in annual forages than in perennial fodder. Hence the entire tree fodders taken up for the study were safe in terms of nitrate content.

Oxalate is an important anti-nutrient that is found sufficiently in large quantities in several fodder crops which may negatively affect the normal growth and development of animals. Soluble oxalate can easily bind with blood calcium to form insoluble calcium oxalate, reducing calcium absorption. This further cause an imbalance in absorbed calcium: phosphorus ratio, resulting in mobilization of bone minerals to alleviate hypocalcaemia. This prolonged mobilization may further lead to osteodystrophy fibrosa (Rahman and Kawamura, 2011).

The present investigation showed that the oxalate content in tree leaves ranged from 1.43 per cent to 2.97 per cent (Table 19). The least oxalate content was observed in *Sesbania grandiflora* (1.43%) whereas both *Musa acuminata* and *Cocos nucifera* have recorded highest oxalate content of 2.97 per cent. Rahman *et al.* (2013) suggested that more than 2 per cent of soluble oxalate in fodder crops may be harmful to the ruminants and fodder with 7-16.6 per cent of oxalate may cause acute poison and death (El-Khodery *et al*., 2008). In the present study all the fodder trees except *Sesbania grandiflora* had oxalate content more than 2 per cent, consequently feeding ruminants solely with these top feeds might produce hypocalcaemia (Rahman *et al*., 2013). Apart from these two anti-nutrients, there are many other ant nutritional factors present in tree fodders which may adversely affect the health of animals. Mimosine, a non protein amino acid present in subabul in which the level of mimosine in the leaf is about 2-6 per cent and varies depending on season and maturity of leaf and stem (Fowomola, 2010). In non-ruminants mimosine toxicity cause alopecia, eye cataracts, poor growth and reproductive problems. More than 5-10 per cent of subabul meal of the diet for poultry, rabbit and swine generally result in poor growth, reproduction and performance. Moreover, mango leaves containing high levels of mangiferin, a phenolic compound which may cause poison to cattle if mango leaves are fed in large amounts (Orwa e*t al*., 2009). Furthermore, cassava leaves have some anti-nutritional factors like cyanide, phytate and tannin and these substances may interfere the digestibility and uptake of the nutrients and may cause adverse effect to other metabolic process in animals (Ly *et al*., 2002).

6. SUMMARY

The investigation entitled 'Performance and carbon sequestration potential of top feedsunder varied planting geometry was carried out as two experiments from 2019 to 2021 to standardize the optimum plant population for higher green forage yield, quality and carbon sequestration potential and to assess the performance for different plant species as top feeds under sole and intercropping system. The study also envisaged to assess the quality of predominant fodder trees and shrubs of southern Kerala.

Field experiment I entitled 'Performance and carbon sequestration potential of top feeds under varied planting geometry with and without intercrop' was conducted at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during April 2019 to April 2021. The experiment was laid out in split-split plot design with two main plot treatments, three sub plot treatments and three sub-sub plot treatments in three replications. The main plot treatments included C_1: sole crop (top feeds), C_2: intercrop (Bajra Napier Hybrid), sub plot treatments F_1: agathi (*Sesbania grandiflora*), F_2: *Erythrina* (*Erythrina indica*) F_3: drumstick (*Moringa oleifera*) and sub-sub plot treatments G_1: 2 m x 1 m, G_2: 2 m x 0.5 m, G_3: paired system. The harvest of main crops *viz*., agathi, *Erythrina* and drumstick were taken at an interval of three months. However, the first harvest of BN hybrid was taken 75 days after planting and subsequent harvests at an interval of 45 days.

The results of the study revealed that cropping systems failed to exhibit significant effect on number of branches of top feeds during first year. However, intercropping top feeds withBajra Napier hybrid recorded 11 per cent increment in number of branches in second year. Among the three selected tree fodders, agathi performed well in terms of number of branches during both the years. Moreover, planting geometry of top feeds did not vary significantly with respect tonumber of branches of top feeds in first year. However, paired system recorded more average number of branches in second year and it was on par with G_1. Regarding C x F interaction, agathi - Bajra Napier hybrid intercropping system recorded more number of branches during both the years and the value was comparable to agathi sole cropping in first year. Furthermore, sole cropping with wider spacing of 2 m x 1 m recorded more number of branches (C_1G_1) than top feeds with narrow spacing of 2 m x 0.5 m. However the interaction between cropping system and spacing failedto exhibit any significant effect on number of branches in second year. Considering the interaction between top feeds and planting geometry, average number of branches was the highest in F_1G_1 and it was comparable to F_1G_2 in first year. However, in the second year, agathi with paired system of planting recorded higher value and it was found to be on par with F_1G_1 and F_1G_2. Furthermore, significant interaction between cropping systems, top feeds and planting geometry on number of branches of top feeds was noticed and significantly higher mean value was noticed when agathi grown as sole crop with 2 m x 1 m geometry ($C_1F_1G_1$) during the first year. However, intercropping agathi with paired system ($C_2F_1G_3$) had higher average branch number in second year and it was found to be on par with $C_2F_1G_2$.

Leaf stem ratio of top feeds did not exhibit significant variation in response to cropping system in first year. However, C_2 was superior in second year. Moreover, agathi exhibited better performance in both first year as well as second year. Among three planting geometry, top feeds with a spacing of 2 m x 1 m was noticed to be significantly superior with respect to leaf stem ratio of top feeds in first year, but, paired system of geometry exhibited betterperformance in second year. The interaction between cropping system and top feeds failed to exhibit any significant effect during first year, while, C_2F_1 exhibited significantly higher average value in second year. Regarding the interaction between cropping system and plantinggeometry, leaf stem ratio was significantly superior for sole cropped top feeds at 2 m x 1 m geometry. However, top feed with paired system of geometry under intercropping system recorded significantly higher value in second year. Moreover, top feed and planting geometry also exhibited a significant interaction with respect to leaf stem ratio and agathi with 2 m x 1 m spacing was noticed to be significantly superior in first year. However, agathi in paired system (F_1G_3) recorded higher value in second year and it was comparable to F_1G_2. Interaction between cropping system, top feeds and planting geometry was non-significant with respect to mean leaf stem ratio of top feeds over first year, however $C_1F_3G_2$ recorded higher valuein second year and it was on par with $C_1F_1G_1$, $C_1F_2G_2$, $C_1F_2G_3$, $C_2F_1G_2$, $C_2F_2G_3$, and $C_2F_3G_2$.

Plant height of Bajra Napier hybrid was higher when it was intercropped with *Erythrina*in first year. However, erythirina was comparable to agathi in second year. Among the three different planting geometry of top feeds, the highest mean plant height of Bajra Napier hybrid was noticed when top feeds were planted at a narrow spacing of 2 m x 0.5 m and it was foundto be on par with that of G_1 in both years. Furthermore, the interaction between top feeds and planting geometry failed to exhibit any significant interaction with respect to plant height during both first and second years.

Leaf stem ratio of Bajra Napier hybrid varied significantly with respect to top feeds and higher value was recorded when intercropped with *Erythrina* while lowest value was for drumstick- BN hybrid plot in both years. Moreover, growing top feeds in a narrow spacing of 2 m x 0.5 m registered significantly higher average leaf stem ratio in first year. However, both G_1 and G_2 recorded significantly higher leaf stem ratio in second year. Regarding the interaction between top feeds and planting geometry, growing *Erythrina* at a narrow spacing of 2 m x 0.5 mrecorded the highest leaf stem ratio in both the years and the value was comparable to that of F_2G_1 in first year and F_2G_1 as well as F_1G_1 in second year.

Average number of tillers was significantly higher when Bajra Napier hybrid was intercropped with *Erythrina* during both the years. Moreover, BN hybrid intercropped with drumstick recorded significantly lowest tiller number in both years. Regarding spacing, 2 m x 0.5 m geometry recorded higher value in both years. However, the value was comparable to 2 m x 1 m spacing in first year. The interaction between top feeds and planting geometry did not differsignificantly during any of the harvests in first year. However, growing

Erythrina at a spacing of 2 m x 0.5 m registered significantly higher value in second year.

Tussock diameter of the Bajra Napier hybrid was higher in *Erythrina* - Bajra Napier hybrid intercropping system during both the years. Moreover, cultivation of top feeds at 2 m x 0.5 m spacing noticed the highest mean tussock diameter and it was on par with the top feeds grown in 2 m x 1 m planting geometry. Furthermore, F x G interaction was non- significant in both the years.

The results of the experiment revealed that cropping system had significant effect on total green fodder yield of top feeds intercropping top feeds with BN hybrid producing significantly more total green fodder yield in both the years. Among the three top feeds, agathi recorded significantly higher total green fodder yield during both years. Moreover, paired system of geometry recorded higher total GFY in first year and it was comparablewith G_2. However, a reverse trend was noticed in second year. Regarding the interaction between cropping system and top feeds, significantly superior value was noticed when agathiwas intercropped with Bajra Napier hybrid over all the harvests in first year as well second year.Considering the interaction between cropping system and planting geometry, higher total green fodder yield was noticed when top feeds were intercropped in 2 m x 0.5 m spacing (C_2G_2) during both the years and it was on par with C_2G_3 (intercropping top feeds in paired system) in first year. The results also revealed that growing agathi at a narrow spacing of 2 m x 0.5 m geometry (F_1G_2) registered significantly higher total green fodder yield in both years. Considering the interaction between cropping system, top feed and spacing, intercropping agathi at geometry of 2 m x 0.5 m ($C_2F_1G_2$) proved to be the best treatment.

The results of the study revealed that growing top feeds along with Bajra Napier hybrid registered significantly higher dry fodder yield in both years. Considering three different top feeds that were grown in subplot, agathi registered significantly higher dry fodder yield in boththe years. Moreover, paired system of planting was found to be significantly superior value in first year. However, growing top feeds at 2 m x 0.5 m recorded the highest value in second year and the value was comparable to that of paired system. The interaction between cropping system and top feeds with respect to total dry fodder yield followed a similar trend as that of green fodder yield. Intercropping agathi with Bajra Napier hybrid (C_2F_1) was significantly higher in both years. Regarding the interaction between cropping system and planting geometry, the highest total dry fodder yield was noticed by C_2G_2 in both the years which was comparable with C_2G_3 in second year. With respect to the interaction between top feeds and planting geometry, growing agathi at 2 m x 0.5 m planting geometry (F_1G_2) was superior during both years. Considering the interaction between cropping system, top feeds and planting geometry, total dry fodder yield as well as dry fodderyield of each harvest over two years was significantly superior in $C_2F_1G_2$.

The mean dry matter content of top feeds did not exhibit any significant interaction withrespect to cropping system and planting geometry during first year. However, among differenttop feeds, highest value was noticed in *Erythrina* and it was on par with drumstick. Dry mattercontent of top feeds during second year varied only with respect to cropping system and C_2 recorded significantly higher value. Dry matter content of top feeds was not significant with respect to the interaction between cropping system and top feeds as well as cropping system and planting geometry. However, dry matter content significantly varied with respect to the interaction between top feeds and planting geometry in both the years and significantly highervalue was noticed by F_2G_1. Dry matter content of top feeds varied significantlywith respect to the interaction between cropping systems, top feeds and planting during secondyear and a higher value was noticed in $C_2F_2G_1$ and it was comparable to that of $C_2F_3G_1$, $C_2F_3G_2$, $C_2F_2G_1$ and $C_1F_3G_2$.

The green fodder yield of BN hybrid over six harvests during first year as wellsecond year revealed that intercropping BN hybrid with *Erythrina* recorded significantly highervalue. Regarding different planting geometry of top feeds, significantly higher total green fodder yield of BN hybrid was noticed when top feeds were planted at 2 m x 0.5 m spacingin both first as well as second year.

Furthermore, the interaction between top feeds and planting geometry was positively influenced and the treatment combination F_2G_1 recorded higher total GFY during first year and it was found to be on par with F_2G_2.

Dry fodder yield of BN hybrid with respect to different top feeds followed the same trend as that of green fodder yield. Intercropping BN hybrid with *Erythrina* recorded significantly higher green fodder yield in all the six harvest during both first year andsecond year. With respect to sub plot factor, significantly higher total dry fodder yield of Bajra Napier hybrid was noticed when top feeds were grown in 2 m x 0.5 m spacing in both the years. Moreover, significant interaction between top feeds and planting geometry was noticed regarding dry fodder yield and the treatment combination F_2G_2 recorded highest value during both years and it was comparable to that of F_2G_1 in second year.

In this study, it was noticed that both cropping system and planting geometry failed to exhibit any significant effect on total chlorophyll content of top feeds. However, among three top feeds, agathi registered significantly higher value in both the years. Moreover total chlorophyll content of top feeds varied significantly with respect to the interaction between cropping systems and top feeds and higher value was noticed by C_1F_1 in both the years and during second year it was on par with C_2F_1. The total chlorophyll content of top feeds was superior in C_1G_2 and it was on par with both C_1G_1 and C_2G_1. The total chlorophyll content did not vary significantly with respect to the interaction between top feed and planting geometry during both the years. The results also revealed that interaction between cropping system, top feeds and planting geometry significantly varied only in second year and growing*Erythrina* as a sole crop in 2 m x 0.5 m planting geometry ($C_1F_2G_2$) registered highest total chlorophyll content and the result was comparable with $C_1F_1G_1$, $C_1F_1G_2$, $C_1F_1G_3$ and $C_2F_1G_1$. Regarding Bajra Napier hybrid, total chlorophyll content of Bajra Napier hybrid was significantly higher when it was intercropped with agathi in first year which was comparable with *Erythrina* in second year. The chlorophyll content of Bajra Napier hybrid did not vary significantly with respect to planting geometry in first year, while growing top feeds at 2 m x 0.5 m geometry recorded significantly higher chlorophyll content in second year. Moreover, significant interaction between top feeds and planting geometry with respect to total chlorophyll content was observed only in second year. Growing agathi in 2 m x 0.5 m geometry(F_1G_2) recorded higher chlorophyll content and it was on par with F_1G_2, F_2G_3 and F_3G_1. Crude protein content of top feeds significantly varied with different cropping systems in first year and C_2 recorded higher value. However, the same treatment recorded significantly lowest crude fibre content in second year of the study. Regarding top feeds, agathi recorded significantly highest crude protein as well as lowest crude fibre content in both years of the study. Regarding planting geometry, G_3 recorded higher crude protein content in first year and it was on par with G_2. However, G_2 recorded significantly more crude protein content in second year. Moreover, lowest crude protein content was noticed in G_1 during first year and it was on par with G_2. Regarding interaction between cropping systems and planting geometry, significantly lower value was noticed in C_1G_3 in second year. Regarding interaction between top feeds and planting geometry, highest crude protein was found in F_1G_2 while F_1G_3 recorded lowest crude fibre content in first year. Interaction between cropping systems, top feeds and planting geometry was significant only in second year. Growing agathi as sole crop in 2 m x 0.5 m geometry ($C_1F_1G_2$) recorded higher crude protein and it was comparable with intercropping agathi in 2 m x 1 m as well as 2 m x 0.5 m geometry ($C_2F_1G_1$ and $C_2F_1G_2$)..

Among the different top feeds, agathi recorded the highest crude protein and the lowest crude fibre content during both the years. Among planting geometries, G_2recorded highest crude protein content in both the years. However, crude fibre content was notsignificant in both the years. Moreover, both crude protein and crude fibre were not significant with respect to the interaction between top feeds and planting geometry.

Among the different treatment combinations, intercropping agathi with 2 m x 0.5 m geometry recorded highest land equivalent ratio, area time equivalent ratio and monetary advantage index. However the highest competitive ratio was noticed when agathi was intercropped with Bajra Napier hybrid in paired system of geometry. However, intercropping drumstick with Bajra Napier hybrid in 2 m x 1 m planting geometry recorded highest aggressivityfollowed by intercropping agathi with Bajra Napier hybrid in 2 m x 0.5 m geometry. Moreoverthe highest relative crowding coefficient was noticed when *Erythrina* was intercropped with Bajra Napier hybrid in 2 m x 1 m geometry.

The study revealed that among different cropping systems, C_2 recorded significantly higher N and K uptake during both the years however the P was non-significant.Among top feeds, F_1 recorded the highest uptake of N, P and K in both years of the study. Regarding planting geometry, highest nitrogen and potassium were recorded by G_2 in both the years. Regarding the interaction between cropping system and op feeds, highest N and K uptakewas noticed by C_2F_1. The P uptake was highest in C_2F_1 in first year, however C_2F_3 recorded highest value in second year and it was on par with both C_2F_1 and C_1F_2. Highest N and K uptakewith respect to the interaction between cropping system and planting geometry was noticed inC_2G_2.Moreover highest N and K uptake with respect to the interaction between top feeds and planting geometry was noticed in F_1G_2 in both the years. Highest N and K uptake was noticed $C_2F_1G_2$ in both years and N uptake was on par with $C_2F_1G_3$.

Significantly greater sequestration of carbon was noticed in C_2 in first and second year. Among top feeds, agathi recorded higher sequestration of carbon in both the years. Moreover, planting top feeds in 2 m x 0.5 m geometry recorded more carbon sequestration in first year and second year. Significant interaction between cropping system and top feeds were noticed with respect to carbon sequestration potential of top feeds and significantly higher value noticed by C_2F_1 in both the years. Similarly C_2G_2 recorded higher level of carbon sequestrationin both years of the study. Carbon sequestration potential of the system significantly varied with respect to the interaction between top feeds and planting geometry and higher value noticed by F_1G_2 in both the years. Moreover, significant interaction between cropping system top feeds and planting geometry were noticed with respect to carbon sequestration and higher value noticed by $C_2F_1G_2$ in both the years.

The organic carbon content in the soil after the experiment significantly varied with respect to different top feeds and higher value noticed by F_1 and it was on par with F_2. However, both pH and EC of the soil did not vary significantly with respect to cropping systems, top feeds as well as planting geometry. Significantly higher organic carbon content in soil was noticed in C_2F_1. Moreover, organic carbon content in the soil after the experiment significantly varied with respect to interaction between cropping systems, top feeds and planting geometry and a higher value was noticed in $C_2F_1G_2$ which was on par with $C_1F_2G_1$, $C_1F_3G_2$, $C_1F_3G_2$, $C_1F_3G_3$, $C_1F_1G_2$, $C_2F_2G_3$, $C_2F_3G_1$ and $C_2F_3G_2$. Among different cropping systems, C_1 recorded more phosphorus and potassium content in the soil after the experiment. Moreover, among different top feeds, F_2 recorded significantly more P and K content in the soil. Moreover, potassium content in the soil after experiment was significantly more in C_1G_2 and it was on par with C_1G_3. Significant interaction between top feeds and planting geometry was recorded with respect to potassium content in the soil and higher value was noticed in F_2G_3 and it was on par with F_3G_2 and F_2G_1.

The results of the study revealed that highest net income and B:C ratio were noticed when Bajra Napier hybrid was intercropped with agathi at 2 m x 0.5 m planting geometry ($C_2F_1G_2$), followed by Intercropping Bajra Napier hybrid with agathi in 2 m x1 m planting geometry ($C_2F_1G_1$). However, sole cropping *Erythrina* in 2 m x 1 m geometry recorded the lowest net returns and B: C ratio during both the years.

Experiment II entitled "Quality assessment of predominant fodder trees and shrubs of southern Kerala for feed quality" revealed that among the ten tree fodders, agathi had highest crude protein (25.24 %) and lowest crude fibre (8.43 %), acid detergent fibre (11.10 %), neutral detergent fibre (17.34 %), oxalate (1.43

%) and negligible content of nitrate. Howeverdrumstick contained more ether extract (7.39%), total ash (12.78%), calcium (2.75%) and magnesium (0.60%). Matti (*Ailanthus triphysa*) had highest nitrogen free extract (64.72%) andlower neutral detergent fibre content (17.54%). Subabul had highest phosphorus (0.93%), iron (222.14 mg kg^{-1}) and calcium: magnesium ratio (5.61) while gliricidia had negligible nitratecontent. Banana was observed as a rich source of potassium (2.70%), manganese (71 mg kg^{-1}),zinc (40.44 mg kg^{-1}), copper (15.7 mg kg^{-1}) and potassium: calcium ratio (2.48). The study revealed that agathi was nutritionally superior to other tree fodders with higher crude protein and lower crude fibre, ADF and anti nutritional factors. Nevertheless, all the ten different top feeds were found to be very good source of nutrients (protein, fibre and minerals) and couldbe used for livestock feeding in fodder scarcity zones of Kerala.

Future line of work

- The study may be replicated with other top feeds which are prevalent in Kerala.
- The possibility of yield improvement by intercropping top feeds with other fodder grass needs to be experimented.
- The possibility of estimation of more antinutritional factors in tree leaves that arecommonly fed to the cattle may be considered.
- The study also points out a scope for *in vitro* analysis of tree fodders.

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APPENDIX I

Weather parameters during the period of experiment

Standard week	First year					Second year				
	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)
	Max	Min	Max	Min		Max	Min	Max	Min	
24	31.1	24.8	93.3	80.0	114.4	32.6	25.7	90.4	74.1	15.0
25	31.9	24.9	90.0	78.7	28.6	32.3	24.5	88.7	73.7	12.8
26	32.1	26.1	87.1	75.3	0.0	31.3	24.7	91.4	76.9	48.4
27	32.2	25.9	90.3	77.1	32.1	32.1	24.6	90.9	75.7	15.1
28	30.8	25.4	90.3	79.0	42.1	32.4	25.2	87.9	72.3	1.4
29	30.1	23.7	94.1	81.6	100.8	31.6	25.0	91.3	74.7	11.4
30	30.4	24.3	92.3	82.4	7.7	31.3	24.2	91.9	76.9	53.0
31	31.5	25.6	89.3	77.6	17.5	30.3	24.3	92.4	81.3	34.2
32	30.0	23.6	94.6	81.7	198.1	30.3	23.8	95.7	80.9	144.7
33	30.4	24.1	91.6	76.6	18.2	32.6	31.3	89.9	68.4	2.0
34	31.1	24.2	92.1	77.4	34.9	32.6	25.6	90.1	72.9	0.0
35	30.7	23.9	93.1	77.9	91.9	32.7	25.9	90.1	72.9	0.0
36	30.9	24.4	90.6	80.1	84.0	31.4	24.7	97.1	76.7	229.9
37	31.3	24.4	88.9	76.4	12.9	30.5	23.9	94.6	89.3	46.9
38	30.9	24.9	91.1	77.9	19.4	30.8	24.3	96.3	90.6	128.6
39	31.0	24.2	93.3	75.6	123.8	31.2	25.1	93.3	87.1	3.4

Standard week	First year					Second year				
	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)
	Max	Min	Max	Min		Max	Min	Max	Min	
41	31.1	24.4	91.7	77.0	133.1	30.7	24.0	95.7	85.9	118.2
42	30.9	24.2	94.9	80.3	125.7	30.7	24.8	93.7	80.9	26.7
43	30.3	23.6	91.3	77.7	42.8	31.9	25.3	90.3	82.7	0.8
44	28.8	24.0	95.0	78.7	105.6	32.4	25.2	88.4	74.7	0.0
45	32.5	24.8	89.3	68.1	0.0	33.2	25.8	92.1	76.3	2.4
46	32.5	24.6	90.7	67.4	9.0	30.6	24.5	94.7	86.1	71.0
47	32.1	24.3	92.4	74.4	49.9	32.6	24.9	91.7	75.3	0.0
48	32.6	24.5	94.0	69.1	31.0	33.0	25.1	88.6	78.1	11.7
49	32.0	24.1	91.3	69.6	38.1	31.3	24.3	93.3	81.7	60.9
50	32.2	23.6	91.0	70.9	53.0	32.8	24.4	93.4	74.7	0.4
51	31.4	23.9	92.9	72.4	41.4	32.2	23.9	94.4	83.4	9.5
52	31.9	23.8	92.7	69.0	60.5	33.2	23.5	89.7	74.0	0.0
1	32.2	24.1	92.3	66.1	0.0	32.0	23.6	94.7	84.0	32.2
2	32.0	22.7	93.4	66.3	45.0	30.4	24.0	94.4	87.9	42.3
3	32.2	22.5	92.3	63.7	10.0	32.0	24.2	92.7	77.3	1.4
4	32.7	23.0	91.4	64.1	0.0	32.6	22.2	92.1	71.6	0.0
5	32.7	22.3	92.7	57.9	0.0	33.0	23.7	91.4	69.1	0.0
6	32.5	23	92.4	63.3	11.2	32.0	23.5	91.2	77.2	0.0
7	32.1	22	92.5	64.3	0.0	33.0	22.1	92.2	87.2	1.2

APPENDIX II
Average input cost and market price of produce

Items	**Cost (₹)**
Inputs	
Labour wage	850 per day
Planting material (BN hybrid)	1 per slip
Agathi seeds	450 kg^{-1}
Erythrina seeds	350 kg^{-1}
Moringa seeds	70 kg^{-1}
FYM	5 kg^{-1}
Urea	8 kg^{-1}
Rajphos	15 kg^{-1}
Muriate of Potash (MOP)	23 kg^{-1}
Market price of produce	
BN hybrid	2 kg^{-1}
Tree fodders	2 kg^{-1}

APPENDIX III

Cost of cultivation (₹ ha^{-1})

Treatments	Cost of cultivation (₹ ha^{-1})
$C_1F_1G_1$	41493.9
$C_1F_1G_2$	39915.08
$C_1F_1G_3$	38491.63
$C_1F_2G_1$	35518.97
$C_1F_2G_2$	36208.2
$C_1F_2G_3$	26346.29
$C_1F_3G_1$	36656.45
$C_1F_3G_2$	37191.45
$C_1F_3G_3$	29672.73
$C_2F_1G_1$	85325.4
$C_2F_1G_2$	95275.01
$C_2F_1G_3$	88161.93
$C_2F_2G_1$	78608.6
$C_2F_2G_2$	84923.42
$C_2F_2G_3$	70084.59
$C_2F_3G_1$	95916.52
$C_2F_3G_2$	85739.87
$C_2F_3G_3$	84583.98

PERFORMANCE AND CARBON SEQUESTRATION POTENTIAL OF TOP FEEDS UNDER VARIED PLANTING GEOMETRY

by

MUBEENA P.
(2018 - 21 - 051)

ABSTRACT
of the thesis submitted in partial fulfillment of the requirement for the degree of

DOCTOR OF PHILOSOPHY IN AGRICULTURE

Faculty of Agriculture
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2022

ABSTRACT

An investigation entitled "Performance and carbon sequestration potential of top feeds under varied planting geometry" was carried out as two experiments at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala from 2018 to 2021 to standardize the optimum plant population for higher green forage yield, quality and carbon sequestration potential, to assess the performance of different plant species as top feeds under sole and intercropping system and to assess the quality of predominant fodder trees and shrubs of southern Kerala.

The study was undertaken as two separate experiments. Experiment I entitled "Performance and carbon sequestration potential of top feeds under varied planting geometry with and without intercrop" was conducted from April 2019 to April 2021 at Instructional Farm, College of Agriculture, Vellayani. The experiment was laid out in split-split plot design with 18 treatment combinations and three replications. The treatments consisted of two cropping systems (C_1-sole crop of top feeds, C_2- intercrop of Bajra Napier hybrid), three top feeds (F_1-agathi (*Sesbania grandiflora*), F_2-erythrina (*Erythrina indica*) F_3- Drumstick (*Moringa oleifera*) and three planting geometry (G_1-2 m x 1 m, G_2- 2 m x 0.5 m, G_3-paired system). The harvest of main crops *viz.*, agathi, erythrina and drumstick were taken at an interval of three months. However the first harvest of Bajra Napier hybrid was taken 75 days after planting and subsequent harvests at an interval of 45 days.

Among cropping systems, intercropping top feeds with Bajra Napier hybrid (C_2) recorded the highest number of branches (10.19) and leaf stem ratio (0.74) in second year and both were non-significant in first year. Among top feeds, agathi recorded significantly more number of branches and leaf stem ratio in both the years. The highest total green fodder yield of 18.60 t ha^{-1} yr^{-1} and total dry fodder yield of 4.76 t ha^{-1} yr^{-1} were noticed in C_2. Agathi recorded significantly the highest total green fodder yield (21.97 t ha^{-1} yr^{-1}) and dry fodder yield (5.57 t ha^{-1} yr^{-1}) and erythrina recorded significantly the lowest yield. However total green fodder yield and dry fodder yield were comparable for both

2 m x 0.5 m (G_2) and paired system (G_3). The highest dry matter content was noticed in C_2 in second year and among different top feeds, erythrina recorded the highest content (25.42%) in the first year. The highest root fresh weight (1369 g plant^{-1}), dry weight (204.25 g plant^{-1}) and root volume (1216.95 cm^{3}plant^{-1}) were observed in C_2 and among top feeds, agathi recorded the highest value.

Plant height, leaf stem ratio, number of tillers and tussock diameter were found to be higher when Bajra Napier hybrid was intercropped with erythrina (F_2) and the same treatment recorded significantly higher total green fodder yield (73.12 t ha^{-1}) and dry fodder yield (18.63 t ha^{-1}). Among planting geometry, G_2 recorded the tallest plant, higher leaf stem ratio, number of tillers and tussock diameter in both the years with significantly higher green fodder yield (75.66 t ha^{-1}) and dry fodder yield (19.24 t ha^{-1}).

Significantly higher crude protein content (20.62 %) and lowest crude fibre content (14.47%) were noticed in C_2 in the second year. Moreover, agathi recorded significantly higher crude protein and the lowest crude fibre content in both years. The treatment G_3 recorded the highest crude protein content in first year (20.69 %) and that of G_2 in second year (21.08 %). However G_2 recorded lowest crude fibre content in second year. Crude protein content of Bajra Napier hybrid was found to be higher in F_1 during first year (9.33 %) and second year (9.74 %). However F_1 recorded the lowest crude fibre content (32.57 %) in the second year. Among planting geometry, G_2 recorded the highest crude protein content during both first year (9.21%) and second year (9.18%).

Total chlorophyll content of top feeds varied significantly with planting geometry and the highest value was noticed in agathi in first (2.19 mg g^{-1}) and second (2.17 mg g^{-1}) year. Total chlorophyll content of Bajra Napier hybrid was the highest in F_1 in first year (1.11 mg g^{-1}) and it was non-significant in second year. Regarding planting geometry, total chlorophyll content of top feeds were non-significant in both the years, however the highest chlorophyll content of Bajra Napier hybrid was noticed in 2 m x 1 m geometry during second year.

Among different treatment combinations, intercropping agathi at 2 m x 0.5 m recorded the highest land equivalent ratio (2.37), area time equivalent ratio

(2.37) and monetary advantage index (158920). The highest competitive ratio of 3.35 was noticed when agathi was intercropped with Bajra Napier hybrid in paired system. However intercropping drumstick with Bajra Napier hybrid in 2 m x 1 m recorded the highest aggressivity of 1.19 followed by intercropping agathi with Bajra Napier hybrid in 2 m x 0.5m (1.10). The highest relative crowding coefficient of 24.34 was noticed when erythrina was intercropped with Bajra Napier hybrid in 2 m x 1 m.

Intercropping top feeds with Bajra Napier hybrid recorded the highest uptake of N and P during first year (50.66 kg ha^{-1} and 93.30 kg ha^{-1}) and second year (54.27 kg ha^{-1} and 106.17 kg ha^{-1}). Among top feeds, agathi recorded high NPK uptake in both the years. Uptake of N and K by top feeds significantly varied with their planting geometry the highest value was noticed by G_2. Phosphorus uptake of top feeds were non-significant with respect to cropping system and planting geometry during first year and G_2 recorded the highest P uptake in second year (39.90 kg ha^{-1}).

Significantly more sequestration of carbon was noticed in C_2 in first (24.57 t ha^{-1}) and second (25.59 t ha^{-1}) year. Among top feeds, agathi recorded higher sequestration of carbon in both the years (18.15 t ha^{-1} and 18.91 t ha^{-1} respectively). Planting top feeds at 2 m x 0.5 m recorded the highest carbon sequestration in the first year (18.13 t ha^{-1}) and the second year (18.87 t ha^{-1}).

The organic carbon content in the soil did not vary significantly in response to cropping system and planting geometry of top feeds. Among three top feeds, the highest carbon content in the soil after the experiment was noticed in agathi (1.26%) and it was comparable with erythrina. Significantly the highest phosphorus (38.27 kg ha^{-1}) and potassium (155.29 kg ha^{-1}) was noticed after sole cropping. Among planting geometry, the highest available P (36.52 kg ha^{-1}) and K (155.13 kg ha^{-1}) content in soil after the experiment was observed in erythrina cultivated plot. However NPK content did not vary significantly with respect to the planting geometry of top feeds.

The economics of cultivation in terms of net return (₹180070 ha^{-1}) and B:C ratio (2.89) were observed to be the highest when agathi was intercropped with Bajra Napier hybrid at 2 m x 0.5 m and the lowest value was registered by intercropping agathi with Bajra Napier hybrid at 2 m x 1 m plant geometry.

Experiment II entitled "Quality assessment of predominant fodder trees and shrubs of southern Kerala for feed quality" revealed that among ten tree fodders, agathi had the highest crude protein (25.24 %) and lowest crude fibre (8.43 %), acid detergent fibre (11.10 %), neutral detergent fibre (17.34 %), oxalate (1.43 %) and negligible content of nitrate. Drumstick contained more ether extract (7.39%), total ash (12.78%), calcium (2.75%) and magnesium (0.60%). Matti (*Ailanthus triphysa*) recorded the highest nitrogen free extract (64.72%) and lower neutral detergent fibre content (17.54%). Subabul recorded the highest phosphorus (0.93%), iron (222.14 ppm) and calcium: magnesium ratio (5.61). Gliricidia had negligible nitrate content. Banana was observed to be a rich source of potassium (2.70%), manganese (71 mg kg^{-1}), zinc (40.44 mg kg^{-1}), copper (15.7 mg kg^{-1}) and potassium: calcium ratio (2.48).

From the study, it could be concluded that intercropping agathi with Bajra Napier hybrid at 2 m x 0.5 m recorded the highest growth, yield, quality, carbon sequestration and economics. However erythrina intercropped with Bajra Napier hybrid at 2 m x 0.5 m recorded the highest plant height, leaf stem ratio, number of tillers, tussock diameter, green fodder yield and dry fodder yield of Bajra Napier. Moreover agathi was found to be nutritionally superior to other tree fodders with high crude protein and lower crude fibre, ADF and antinutritional factors. Nevertheless, all the ten different top feeds were observed to be good source of nutrients (protein, fibre and minerals) and could be used for livestock feeding in fodder scarcity zones of Kerala.

സംഗ്രഹം

"വിവിധ വൃക്ഷ തീറ്റവിളകളുടെ പ്രകടനവും കാർബൺ സംഭരണവും വ്യത്യസ്ത നടീൽ ജ്യാമിതിയിൽ" എന്ന വിഷയത്തെ ആസ്പദമാക്കി വെള്ളായണി കാർഷിക കോളേജിൽ 2018-2021 കാലയളവിൽ ഒരു ഗവേഷണ പഠനം നടത്തുകയുണ്ടായി. പരമാവധി പച്ചപ്പുല്ല് വിളവ്, കൂടുതൽ ഗുണ നിലവാരം, കാർബൺ സംഭരണം എന്നിവ ലഭ്യമാവുന്ന രീതിയിൽ തീറ്റ വിളകളുടെ എണ്ണം ക്രമീകരിക്കുക, വൃക്ഷ തീറ്റവിളകൾ ഏകവിളയായും ഇടവിളയായും കൃഷി ചെയ്യുമ്പോൾ പ്രകടനത്തിൽ ഉണ്ടാവുന്ന വ്യത്യാസം വിലയിരുത്തുക, തെക്കൻ കേരളത്തിലെ പ്രധാന വൃക്ഷ തീറ്റവിളകളുടെ ഗുണ നിലവാരം വിലയിരുത്തുക എന്നിവയായിരുന്നു പ്രധാന ലക്ഷ്യങ്ങൾ. രണ്ടു വ്യത്യസ്ത പരീക്ഷണങ്ങളായിട്ടാണ് ഗവേഷണം നടത്തിയത്.

വിവിധ വൃക്ഷ തീറ്റവിളകളുടെ പ്രകടനവും കാർബൺ സംഭരണവും വ്യത്യസ്ത നടീൽ ജ്യാമിതിയിൽ ഇടവിളയോടൊപ്പവും അല്ലാതെയും" എന്ന തലക്കെട്ടിനെ ആസ്പദമാക്കി നടത്തിയ ഒന്നാമത്തെ പരീക്ഷണം ഏപ്രിൽ 2019 മുതൽ ഏപ്രിൽ 2021 വരെ വെള്ളായണി കാർഷിക കോളേജിലെ ഇൻസ്ട്രക്ഷണൽ ഫാമിൽ നടത്തുകയുണ്ടായി. പരീക്ഷണത്തിനായി രണ്ടു വ്യത്യസ്ത വിളവെടുപ്പ് സമ്പ്രദായങ്ങൾ (ഏകവിള, ഇടവിള), മൂന്ന് വൃക്ഷ തീറ്റവിളകൾ (അഗത്തി, മുരിക്ക്, മുരിങ്ങ), മൂന്ന് നടീൽ ജ്യാമിതികൾ (2 മീ x 0 .5 മീ, 2 മീ x 1 മീ, ജോഡി സമ്പ്രദായം) എന്നിവയാണ് ഉപയോഗപ്പെടുത്തിയത്. മൂന്ന് അവർത്തനങ്ങളിലായി 18 ട്രീറ്റ്മെൻറ് കോമ്പിനേഷനുകളിലായി സ്പ്ലിറ്റ് - സ്പ്ലിറ്റ് ഡിസൈനിലാണ് പരീക്ഷണം നടത്തിയത്.

വിളവെടുപ്പ് സമ്പ്രദായങ്ങളിൽ വൃക്ഷ തീറ്റവിളകൾ സങ്കരനെപിയറുമായി ഇടകലർത്തി കൃഷി ചെയ്യപ്പോൾ വൃക്ഷ തീറ്റവിളകളിൽ കൂടുതൽ ചില്ലകൾ, ഇല തണ്ട് അനുപാതം, ഉയർന്ന പച്ചപ്പുല്ല് വിളവ് (18 .60 ടൺ/ ഹെക്ടർ), ഉണക്കപ്പുല്ല് വിളവ് (4 .76 ടൺ/ ഹെക്ടർ) എന്നിവ രേഖപ്പെടുത്തി. കൂടാതെ വൃക്ഷ തീറ്റവിളകളുടെ കൂട്ടത്തിൽ കൂടുതൽ പച്ചപ്പുല്ലിന്റെയും ഉണക്കപുല്ലിന്റെയും വിളവ് അഗത്തിയിലും കുറഞ്ഞ വിളവ് മുരിക്കിലും രേഖപ്പെടുത്തി. വ്യത്യസ്ത നടീൽ ജ്യാമിതികളിൽ, വൃക്ഷ തീറ്റവിളകൾ 2 മീ x 0 .5 മീ അകലത്തിൽ നട്ടപ്പോഴും ജോഡി സമ്പ്രദായത്തിൽ നട്ടപ്പോഴും ഏകദേശം ഒരേ രീതിയിലുള്ള പച്ചപ്പുല്ല് വിളവാണ് ലഭിച്ചത്. കൂടാതെ അഗത്തി സങ്കര നേപ്പിയറുമായി ഇടകലർത്തി നട്ടപ്പോൾ അഗത്തിയുടെ വേരുകൾക്ക് മറ്റു രണ്ടു തീറ്റവിളകളേക്കാൾ കൂടുതൽ ഭാരവും വ്യാപ്തവും കണ്ടെത്തി.

സങ്കര നേപ്പിയർ മുരിക്കിൻറെ. കൂടെ ഇടവിളയായി കൃഷി ചെയ്തപ്പോൾ മറ്റു രണ്ടു തീറ്റവിളകൾക്കൊപ്പം നട്ടതിനേക്കാൾ കൂടുതൽ ചെടിയുടെ നീളം, ഇല തണ്ട് അനുപാതം, ചിനപ്പുകളുടെ എണ്ണം, ഉയർന്ന പച്ചപ്പുല്ല് വിളവ് (73.12 ടൺ/ ഹെക്ടർ), ഉണക്കപ്പുല്ല് വിളവ് (18 .63 ടൺ/ ഹെക്ടർ) എന്നിവ രേഖപ്പെടുത്തി.

വൃക്ഷ തീറ്റവിളകൾ സങ്കര നേപ്പിയറുമായി ഇടവിളയായി കൃഷി ചെയ്തപ്പോഴും, വൃക്ഷ തീറ്റവിളകളിൽ അഗത്തിയിലും, നടീൽ ജ്യാമിതികളിൽ 2 മീ x 0 .5 മീ ലും കൂടുതൽ അളവിൽ അസംസ്കൃത മാംസ്യവും, ക്ലോറോഫില്ലിന്റെ അളവും കുറഞ്ഞ തോതിൽ അസംസ്കൃത നാരും കണ്ടെത്തി.

അഗത്തി 2 മീ x 0 .5 മീ അകലത്തിൽ സങ്കരനേപ്പിയറിനോടൊപ്പം ഇടവിളയായി കൃഷി ചെയ്തപ്പോൾ പോഷക മൂല്യങ്ങൾ കൂടുതലായി വലിച്ചെടുക്കുന്നതിനോടൊപ്പം കാർബൺ സംഭരണത്തിന്റെ അളവ്, ജൈവികക്ഷമത, വരവ് ചെലവ് അനുപാതം (2.89) എന്നിവയും കൂടുതലായി രേഖപ്പെടുത്തി. കൂടാതെ മണ്ണിൽ ലഭ്യമായ പോഷകങ്ങളുടെ അളവ്, വിളവെടുപ്പ് സമ്പ്രദായതിനും വൃക്ഷ തീറ്റ വിളകൾക്കും അനുസൃതമായി ഗണ്യമായി മാറുന്നതായി കണ്ടെത്തി.

തെക്കൻ കേരളത്തിലെ പ്രധാന വൃക്ഷ തീറ്റവിളകളിലെ പോഷക മൂല്യത്തെ അടിസ്ഥാനമാക്കി നടത്തിയ രണ്ടാമത്തെ പരീക്ഷണത്തിന് പത്ത് വൃക്ഷ തീറ്റവിളകളെയാണ് പഠനവിധേയമാക്കിയത്. അവയിൽ അഗത്തിയിൽ മറ്റു വൃക്ഷ തീറ്റവിളകളേക്കാൾ ഉയർന്ന അളവിൽ അസംസ്കൃത മാംസ്യം (25.24%), കുറഞ്ഞ അളവിൽ അസംസ്കൃത നാര് (8 .43 %), ആസിഡ് ഡിറ്റർജന്റ് ഫൈബർ (11 .10 %), ന്യൂട്രൽ ഡിറ്റർജന്റ് ഫൈബർ (17 .34 %) എന്നിവ രേഖപ്പെടുത്തി. കൂടാതെ മുരിങ്ങയിലയിൽ ഉയർന്ന അളവിൽ കാൽസ്യം, മഗ്നീഷ്യം എന്നിവ കണ്ടെത്തി. പീലിവാകയിൽ കൂടുതലായി ഫോസ്ഫറസ്, ഇരുമ്പ് എന്നിവയും വാഴയിൽ ഉയർന്ന അളവിൽ പൊട്ടാസിയം, സിങ്ക്, കോപ്പർ എന്നിവയും കാണാൻ സാധിച്ചു. കൂടാതെ തിരഞ്ഞെടുത്ത പത്ത് വൃക്ഷ തീറ്റവിളകളിലും പോഷക വിരുദ്ധ ഘടകങ്ങളായ നൈട്രേറ്റ്, ഓക്സലേറ്റ് എന്നിവയുടെ അളവ് കന്നുകാലികൾക്ക് അപകടകരമല്ലാത്ത തോതിലാണ് കാണപ്പെട്ടത്.