INTERCROPPING FODDER LEGUMES IN PALISADE GRASS (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.)

by

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(2016-11-023)

THESIS

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DECLARATION

I, hereby declare that this thesis, entitled **"INTERCROPPING FODDER LEGUMES IN PALISADE GRASS (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.)** " is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

et al.	And co workers
@	At the rate of
BCR	Benefit cost ratio
cm	Centimetre
CD	Critical difference
LAI	Leaf Area Index
LER	Land Equivalent Ratio
LEC	Land Equivalent Coefficient
L:S	Leaf Stem ratio
^oC	Degree Celsius
^oE	Degree East
^oN	Degree North
CEY	Crop equivalent yield
MEY	Maize Equivalent Yield
dS m^{-1}	Deci Siemens per metre
FYM	Farmyard manure
Fig.	Figure
ha	Hectare
kg	Kilogram
kg ha^{-1}	Kilogram per hectare

$Mg\ m^{-3}$	Mega gram per cubic metre
N	Nitrogen
NS	Non significant
No.	Number
%	Per cent
ha^{-1}	Per hectare
P_2O_5	Phosphate
P	Phosphorus
K_2O	Potash
K	Potassium
RH	Relative humidity
₹	Rupees
SE	Standard error
i.e.	That is
$t\ ha^{-1}$	Tonnes per hectare

INTRODUCTION

1. INTRODUCTION

India is gifted with the largest livestock population in the world. It accounts for about 57.3 per cent of the world's buffalo population and 14.7 per cent of the cattle population. Livestock population is around 529.7 million and is expected to grow at the rate of 0.55 per cent in the coming years (IGFRI, 2013). The average production of milk and meat in the country is lower than the global average. Further, their production potential is not realized fully because of constraints related to feeding, breeding, health and management.

Shortage of good quality forage is a major constraint to dairy cattle productivity. Deficiency of feed and fodder (50.2 per cent) accounts for half of the total loss in livestock production. At present there exist a severe deficit of green fodder (36 per cent), dry fodder (40 per cent) and concentrates (57 per cent) at national level (AFDP, 2011).

Presently, area under fodder crops in India is around 8.6 million hectare. Expansion of area for fodder cultivation is not possible due to increased competition between various land uses for the cultivable land. In this context, fodder production system needs intensification by increasing the biomass per unit area per unit time. Integration of fodder legumes in grass based fodder production system is the most efficient alternative and economical way to increase quality fodder production. The importance of intercropping in farming systems has been well recognized in India. The yield advantage occurs in intercropping system, as the component crops differ in such a way that when they are grown together they complement each other and utilize the resources most effectively.

Palisade grass (*Brachiaria brizantha*) is a quick growing, high yielding fodder crop best suited to the tropical humid conditions. The crop is very aggressive, resistant to drought, compete effectively with other species and quickly cover the ground. It is reported to grow and give higher yield when grown on acid soils than alkaline soils. This grass is valuable for cut and carry feeding system. Trials carried out by All India Coordinated Research Project on Forage Crops at Vellayani has proved that palisade grass is suitable for Kerala conditions. According to the reports of IGFRI the green fodder yield of palisade grass variety Mulato was comparable to that of guinea grass (IGFRI, 2009).

Fodder cowpea (*Vigna unguiculata*) is a heavy forage yielder grown both as a pure crop or in combination with grasses. It has shade tolerance, quick growth and rapid ground covering ability. Apart from improving the fertility status of the soil it reduces the nitrogen requirement of companion crops. The feeding value of fodder cowpea is more than other legumes. It is a highly nutritious fodder, rich in proteins, amino acids, calcium, phosphorus and vitamins.

Rice bean (*Vigna umbellata*) is a promising multipurpose fodder legume with a good potential to be used as food and fodder. It is a less known, underutilized fodder legume that can be intercropped with wide spaced row crops. The crop is adapted to high temperature, humidity and heavy soils. It is a good source of carbohydrates, proteins, minerals and vitamins to the dairy cattle.

It is well established that, livestock feed should contain sufficient nutrients, particularly proteins. The nutritional value of perennial tropical grasses may sometimes become insufficient to maintain higher rates of milk production. The sowing of legumes along with grasses not only improves the quality of fodder but also helps to ensure yield stability through enhanced fodder production. Morover, the type of intercrop and their spatial arrangement plays an important role in maintaining the balance of competition between component crops and their productivity.

With this back ground, the present study was undertaken with to evaluate the production potential of intercropping fodder legumes in palisade grass in terms of yield and quality and to assess the biological and economic efficiency of the intercropping system.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Fodder legumes are agronomically sound, environmentally friendly and economically advantageous. Integrating legumes in the fodder production system is one of the most efficient means to enhance yield and quality. Fodder cowpea and fodder rice bean are highly nutritious and palatable fodder legumes. *Brachiaria brizantha* commonly known as palisade grass is an important forage grass of the tropics with good yield potential, palatability, persistence and quality fodder. The literature pertaining to intercropping and plant spacing are reviewed in this chapter. Wherever sufficient literature on *Brachiaria*, fodder cowpea and fodder rice bean is not available, results on related fodder crops are also reviewed.

2.1. EFFECT OF INTERCROPPING AND PLANT SPACING ON GROWTH PARAMERTERS

2.1.1. Plant height

Marchiol *et al.* (1992) reported that plant height of soybean increased when intercropped with maize. The height of bajra napier hybrid was increased when fodder cowpea was grown as intercrop (Jayakumar, 1997). Plant height of maize was decreased with increased percentage of legume seeds in maize - cowpea mixture (Ibrahim *et al.,* 2006). Bakhashwain (2010) observed that plant height of rhodes grass decreased when the ratio of alfalfa was increased in the rhodes grass-alfalfa mixture. Nadeem *et al.* (2010) found out that among different cereal - legume mixtures, highest plant height was obtained for oats + vetch mixture. Plant height of guinea grass (*Panicum maximum*) was highest when intercropped with *L.purpurious* and was on par with sole crop of guinea grass.

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) found out 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.

2.1.2. No of tillers / branches plant^{-1}

Jayakumar (1997) observed that bajra napier hybrid produced more number of tillers when intercropped with legumes in paired rows. Orak *et al.* (1999) found out that more number of tillers were produced by barley- vetch mixture compared to their sole crops. Canon and orak (2002) observed that among different grass-legume mixtures barley-vetch mixture, produced higher number of tillers/branches. Increased seed ratio of alfafa in rhodes-alfalfa mixture resulted in more number of branches (Bakashwain, 2010).

Purushotham and Siddaraju (2003) found out that guinea grass planted at a wider spacing of 60 cm × 60 cm produced more number of tillers than 30 or 45 cm. According to Velayudham *et al.* (2011) adoption of a wider spacing of 60 cm × 50 cm recorded higher number of tillers than 50 cm × 50 cm. Manjunatha *et al.* (2013) revealed 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).

2.1.3. Leaf: stem ratio

Jayakumar (1997) observed that intercropping fodder cowpea and lablab bean in hybrid napier did not show any significant effect on leaf: stem ratio of bajra napier hybrid whereas pure crop of bajra napier hybrid recorded highest L: S ratio. Nadeem *et al.* (2010) reported that among different grass-legume mixtures highest leaf-stem ratio was obtained for oats-vetch (0.85) followed by barley - vetch mixture (0.73).

Velayudham *et al*. (2011) observed that adoption of different level of spacing in hybrid napier did not show any significant effect on leaf: stem ratio. Sharu (2016) found out that palisade grass planted with spacing of 60 cm × 30 cm and 60 cm × 40 cm gave higher leaf: stem ratio than 60 cm × 60 cm spacing.

2.1.4. Leaf Area Index

Lazaridou *et al*. (2012) found out that alfalfa-tall fescue mixture significantly decreased the leaf area index of alfalfa. Alalada *et al*. (2013) reported increased LAI of *Panicum maximum* when intercropped with *Stylosanthes hamata.*

Thavaprakash *et al*. (2005) reported that baby corn planted at a wider spacing of 60 cm × 19 cm gave higher leaf area index than a closer spacing of 45 cm × 15 cm. According to Sharu (2016) among different level of spacing adopted in palisade grass highest LAI was observed in 60 cm × 30 cm (4.70) followed by 60 cm × 40 cm (3.92)

2.2. EFFECT OF INTERCROPPING AND PLANT SPACING ON YIELD PARAMERTERS

2.2.1. Green fodder yield

Jayakumar (1988) revealed that intercropping guinea grass with fodder maize and fodder cowpea increased the total green fodder yield compared to sole crop of guinea grass. Angadi and Gumastae (1989) revealed that maize intercropped with seven legumes recorded highest green fodder yield compared to pure crop of maize. Shahapurkar and Patil (1989) reported that maize intercropping with cowpea had no significant influence on yield of maize. Choubey *et al.* (1997) found out that intercropping palisade grass with rice bean gave the higher green fodder yield. Reddy and Naik (1999) revealed that hybrid napier intercropped with cowpea produced a higher green fodder yield of 33.6 t ha^{-1}. According to Jayakumar (1997) hybrid napier planted in paired row and intercropped with fodder cowpea and lablab bean recorded maximum green fodder yield compared to their pure crop. Lakshmi *et* *al*. (2002) revealed that an intercropping system of hybrid napier + *Stylosanthes hamata* significantly recorded higher green fodder yield (172.55 t ha^{-1}) and dry matter yield (87.3 t ha^{-1}). Among annual legume intercropping systems, hybrid napier + cowpea recorded higher green fodder yield (136.94 t ha^{-1}) and dry fodder yield (50.10 t ha^{-1}). Olanite *et al*. (2004) observed that among different grass-legume combinations higher green fodder yield was obtained for *Centrosema pubescense* with *Brachiaria ruziziensis* and *Centrosema nlemfuensise*. Naveenkumar and Naleeni (2006) observed that the 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.

Ibrahim *et al.* (2006) found out that among different seed proportions of fodder maize and fodder cowpea higher green fodder yield was obtained for the ratio 75:25. The research conducted by Meena *et al*. (2008) at Avikanagar (Rajasthan) revealed that intercropping system of dhaman grass with cowpea at 1:2 row proportions recorded significantly higher green fodder yield (134.48 q ha^{-1}) and dry fodder yield (36.16 q ha^{-1}) as compared to 1:1 and 2:1 row proportions of dhaman grass and cowpea intercropping (109.09, 33.45 and 92.82, 26.68 q ha^{-1}, respectively). Nadeem *et al*. (2010) found out that among different cereal fodder - legume mixtures, maximum green fodder yield was recorded by oats +vetch mixture followed by barley + vetch mixture. Alaladae *et al.* (2013) reported increased biomass yield in *Panicum maximum* when intercropped with *Stylosanthes hamata.*

According to Chhilar and Tomar (1970) hybrid napier planted with a spacing of 60 cm × 30 cm recorded higher green fodder yield than 60 cm × 50 cm spacing. Munigowda *et al.* (1989) found out that BH-18 variety of hybrid napier grown at a closer spacing of 60 cm × 30 cm gave higher green fodder yield. 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 mott elephant grass. Sharma (2013) revealed that sewan grass grown at a closer spacing of 25 cm gave higher green fodder yield than a spacing of 75 cm. Sharu (2016) observed that among different levels of spacing adopted in palisade grass, maximum green fodder yield was obtained for a narrow spacing of 60 cm × 30 cm.

2.2.2. Dry fodder yield

Gill and Ganwar (1990) conducted an experiment to evaluate the intensive fodder production under guava plantation and found out that pure crop of hybrid napier gave higher dry fodder yield followed by hybrid napier + cowpea and guinea grass + cowpea. Marchiol *et al.* (1992) reported that dry fodder yield obtained from maize-soyabean intercropping was 8.9 % higher than pure stand of soyabean and 4% greater than sole crop of maize. A mixture of grass (*Chloris gayana*) with the legume (*Stylosanthes guianensis*) at 1:3 ratio resulted in increased herbage dry matter yield (Onifade *et al.*, 1994). Choubey *et al.* (1997) revealed that higher dry fodder yield was obtained by *Brachiaria brizantha* intercropped with *Vigna umbellata.* Ezenwa and Akenova (1998) reported that mixtures of selected grasses and adapted herbaceous legumes in south-west Nigeria produced 22-154% more dry matter yield than their respective pure grasses. The maximum dry matter yield was obtained by sowing fodder maize and cowpea in the ratio of 3:1 (Ibrahim *et al.,* 2006). Baba *et al.* (2011) reported that guinea-centro (2:2 and 3:1) mixtures produced higher total dry matter yields than their respective monocultures. Nadeem *et al.* (2010) observed that among grass-legume mixtures, maximum dry fodder yield was obtained for oats + vetch mixture followed by barley + vetch and wheat + vetch. Meena *et al.* (2011) reported that Intercropping of *Vigna unguiculata* and *Cenchrus setigerus* in the ratio of 2:1 gave maximum dry fodder yield of 3.35 t ha^{-1}. Albayrak *et al.* (2013) reported that alfalfa-smooth brome grass mixture recorded higher dry matter yield.

Bhatti *et al.* (1985) stated that elephant grass grown at a closer spacing of 50 cm ×50 cm recorded higher dry fodder yield than 60 cm × 60 cm and 70 cm ×70 cm spacing. Bhagat *et al.* (1992) reported that hybrid napier planted at a row spacing of 1m gave higher dry matter yield. Wijitphan *et al.* (2009) observed that napier grass grown at a spacing of 50 cm × 40 cm gave higher total dry matter yield of 70.84 t ha^{-1} compared to spacings of 50 cm × 60 cm, 50 cm ×80 cm and 50 ×100 cm. Manjunatha *et al.* (2013) found out that fodder sorghum planted with row spacing of 45 cm recorded higher dry fodder yield than 30 cm row spacing. According to Sharu (2016) palisade grass grown at a spacing of 60 cm × 30 cm gave maximum dry fodder yield compared to spacing of 60 cm × 40 cm and 60 cm × 60 cm.

2.3. EFFECT OF INTERCROPPING AND PLANT SPACING ON LAND USE EFFICIENCY AND BIOLOGICAL EFFICIENCY

2.3.1. Land Equivalent Ratio

Land equivalent ratio (LER) index is used to evaluate the efficiency of intercropping in 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. Intercropping of sorghum with soybean in normal planting of 45 cm x 10 cm registered significantly higher land equivalent ratio of 1.75 (Desale *et al.*, 2002). Highest land equivalent ratio of 1.35 was observed in intercropping of sorghum with cowpea 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) revealed that sorghum intercropped with fodder cowpea in 1:1 row proportion gave the best total LER of 2.11. Zahid *et al.* (2013) reported that intercropping of maize with french bean at 1:2 row proportion, maize with mung bean at 1:1 row proportion and maize with mung bean at 1:2 row proportion were on par.

2.3.2. Land Equivalent Coefficient

Kumar *et al.* (2012) opined that intercropping maize with field bean with 100 per cent NPK to both the crops recorded significantly higher land equivalent coefficient of 0.43. Choudhary (2014) found out that among different row ratios, highest LEC was obtained with 1:2 row ratio in maize-french bean intercropping, followed by 1:5 and 1:1 and among legumes highest LEC was registered for french bean followed by cowpea and black gram.

2.3.3. Aggressivity

Aggressivity is an index which compares the yields between intercropping and pure cropping, and also their respective land occupancy. The productivity of the dominant species directly influences the performance of the intercropping communities (Li *et al.*, 2001). Mahapatra (2011) reported that when sabai grass was intercropped with black gram in row ratios of 1:1, 1:2 and 3:5, highest aggressivity of 3.53 was registered with 1:2 row ratio. Kumar *et al.* (2012) observed minimum aggressivity (-0.002) when maize was intercropped with field bean.

2.3.4. Crop Equivalent Yield

Padhi (2001) stated that intercropping maize with runner bean at 2:2 row proportion produced significantly higher maize equivalent yield of 63.69 q ha^{-1} compared to sole maize (27.11 q ha^{-1}). According to Marer (2005) Intercropping maize with pigeon pea recorded significantly higher MEY of 8076 kg ha^{-1} at 4:2 row ratio where 50 % pigeon pea population is maintained as additive series as compared to replacement series. Meena *et al.* (2006) opined that highest maize equivalent yield was registered by intercropping maize with soybean in 2:2 row ratio than 1:1 row ratio. Mallikarjuna *et al.* (2010) reported that paired row of maize with two rows of urd bean recorded significantly higher maize equivalent yield (68.90 q ha^{-1}) and land equivalent ratio (1.68) as compared to sole maize). Reddy and Pallad (2016) reported that simultaneous sowing of maize + fodder cowpea in 1:1 row proportion recorded significantly higher MEY of 6742 kg ha^{-1}.

2.4. EFFECT OF INTERCROPPING AND PLANT SPACING ON QUALITY PARAMETERS

2.4.1. Crude protein content

Hong *et al.* (1987) observed an improvement in crude protein content of maize when intercropped with soybean. Marchiol *et al.* (1992) found out that higher crude protein content of maize-cowpea mixture compared to pure crop of maize. Meena *et al.* (2008) stated that dhaman grass intercropped with cowpea at 1:2 row proportion recorded significantly higher crude protein content of 13.66 % compared to 1:1 and 2:1 row proportions of dhaman grass and cowpea intercropping (10.44 and 8.44 %, respectively). Jayakumar (1997) observed that grass intercropping with legumes recorded highest crude protein yield. Tripathi *et al.* (1997) reported that maize intercropped with cowpea gave maximum crude protein content. Reddy and Naik (1999) reported that hybrid napier intercropped with cowpea gave a higher crude protein content of 916.0 kg ha^{-1}. Mapairwe *et al.* (2002) revealed that cereal-legume intercropping gave higher crude protein content when compared to their pure crops. Gopalan *et al.* (2003) reported improvement in crude protein content of bajra napier hybrid when intercropped with *D.virgatus*. Olanite *et al.* (2004) found out that in grass-legume mixtures legume crude protein content was more than that in pure grasses. Combination of *Centrosema pubescense* with *Brachiaria ruziziensis* gave maximum legume protein content. Bolko (2004) reported that when fodder maize and pearl millet was intercropped with cowpea and dolichos bean higher crude protein content was recorded. Ibrahim *et al.* (2006) revealed that pure crop of fodder cowpea recorded higher crude protein content followed by fodder maize - fodder cowpea mixture sown in 1:3 proportion. Katoch and Marwah (2006) observed that hybrid napier - soyabean mixture recorded higher crude protein content. Meena *et al.* (2011) reported that intercropping of cowpea with *Centrosema setigerus* in 2:1

row proportion produced higher crude protein content. Intercropping fodder maize with lablab bean significantly increased the crude protein content and reduced the crude fibre content (Khogali *et al.*, 2011).

Singh *et al.* (2008) revealed that higher crude protein content was recorded under the crop geometry of 60 x 20 cm and 60 x 15 cm as compared to 45 x 20 cm, 45 x15 cm, 30 x 20 cm and 30 x 15 cm in forage maize. Wijitphan *et al.* (2009) stated that crude protein content of napier grass grown at a spacing of 50 cm × 60 cm and 50 cm ×80 cm were on par. Velayudham *et al.* (2011) reported that the different levels of spacing adopted in bajra napier hybrid grass did not influence the crude protein content. Sharma (2013) observed that sewan grass planted at row spacing of 25 cm recorded 9 per cent more crude protein content than 75 cm spacing. Ahmad *et al.* (2014) found out that baby corn grown at a spacing of 60 cm × 20 cm produced higher crude protein content compared to other closer spacing. According to Sharu (2016) palisade grass grown at narrow spacing of 60 cm × 30 cm recorded maximum crude protein content.

2.4.2. Crude fibre content

Ayub *et al.* (2004) reported that rice bean and sorghum sown alone had lowest while highest crude fibre contents was recorded when sorghum and rice bean were sown at different seed proportions. The decreased crude fibre contents of the mixture with increased seed rate of rice bean may be due to low fibre contents of rice bean than sorghum sown alone. Ibrahim *et al.* (2006) found out that sole crop of maize recorded highest crude fibre content (34.51%) when maize and cowpea were sown in different seed proportion and lowest crude fibre content was recorded by cowpea alone. Khogali *et al.* (2011) reported lower crude fibre content in fodder maize intercropped with lablab bean and improved the nutritional value of maize. Ojo *et al.* (2013) revealed that sole crop *of Panicum maximum* recorded higher crude fibre content than *Panicum - L.purpureus* intercropping.

2.5. EFFECT OF INTERCROPPING AND PLANT SPACING ON SOIL NUTRIENT STATUS

Legume enriches soil by biological nitrogen fixation. It can replace nitrogen fertilizer either fully or partly (Fujita *et al.*, 1992). According to Balyan (1997) intercropping systems resulted in marked increase in soil organic carbon content (%) than sole crop. Maize with guar (green manure) intercropping system caused significantly higher organic carbon than maize with guar (fodder) and maize with greengram. Jayakumar (1997) reported that plots of hybrid napier intercropped with lablab bean recorded higher content of N, P and K. Meena *et al.* (2011) found out that Intercropping of cowpea (*Vigna unguiculata*) and *Cenchrus setigerus* in 2:1 ratio gave higher organic carbon content, available N and P. Marer, (2005) observed that intercropping of cereals with pigeonpea resulted higher soil available nitrogen. Padhi and Panigrahi, (2006) concluded that legumes like black gram, soybean and groundnut when intercropped with maize resulted in significantly higher available soil N content and decreased available soil P and K content. Intercropping maize with cowpea resulted in increased amount of available nutrients compared to sole cropping of maize (Dahmardeh *et al.,* 2010). Kumar *et al.* (2012) stated that maize intercropped with field bean with 100 per cent N, P and K to both the crops recorded significantly higher available N, P and K status of soil.

2.6. EFFECT OF INTERCROPPING AND PLANT SPACING ON UPTAKE OF NUTRIENTS

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 increases the N uptake by grass. Srinivasraju *et al.* (1997) concluded that intercropping maize with cowpea resulted in increased N, P and K uptake of the system than sole cropping. Jayakumar (1997) revealed that intercropping of hybrid napier with lablab bean recorded maximum N uptake

(113.10kg ha^{-1}) and P uptake (16.48 kg ha^{-1}). Saren and Jana (1999) reported that total NPK uptake was higher in maize intercropped with pigeon pea than pure stand of either crop. Singh *et al.* (2000) reported that maize intercropped with pea resulted in increased nitrogen content compared to maize intercropped with lentil and pure crop of maize. Intercropping of maize with cowpea resulted in enhanced N, P and K uptake of the system compared to pure cropping (Ramanakumar and Bhanumurthy, 2001). Adhikari *et al.* (2005) reported that maize intercropped with groundnut in 2:2 row proportion exhibited higher uptake of N, P and K than maize intercropped with groundnut in 1:1 row proportion. The total N, P and K uptake of the system was significantly higher in intercropping system than pure cropping (Singh *et al.*, 2008). Sharu (2016) observed that N, P and K uptake was higher in palisade grass grown at a narrow spacing of 60 cm × 30 cm.

2.7. EFFECT OF INTERCROPPING AND PLANT SPACING ON ECONOMICS

Bhagat *et al.* (1992) observed that hybrid napier grown at a wider row spacing of 1.0 m fetched higher net returns of 12,047 ₹ ha^{-1} yr^{-1} than narrow spacing. According to Manjunatha *et al.* (2013) among different row spacing adopted in perennial fodder sorghum, 45 cm registered maximum gross income, net income and B: C ratio compared to 30 cm row spacing. Bai and Pillai (1993) obtained higher returns by intercropping sorghum with velvet bean (₹ 3,475 ha^{-1}) than the sole sorghum (₹.2,180 ha^{-1}). Maximum net returns was obtained from maize - cowpea intercropping (₹.4,865 ha^{-1}) system than sole cropping of maize (₹.3,310 ha^{-1}) Ramachandra *et al.* (1993). Jayanthi *et al.* (1994) concluded that fodder sorghum - cowpea intercrop combination at 1:1 ratio produced higher net returns (₹.3,340 ha^{-1}) than pure crop of sorghum (₹.2,600 ha^{-1}). Barik and Tiwari (1996) stated that maize intercropped with cowpea produced higher gross monetary returns than pure crop of maize. The intercropping of maize with cowpea in the row proportion of 2:2 resulted in significantly higher gross return of ₹ 15, 236 ha^{-1}, net return of ₹ 8,346 ha^{-1} and benefit cost ratio of 2.21 (Sunilkumar *et al.*, 2005). Sharma *et al.* (2008) concluded that the intercropping of maize with cowpea in the row proportion of 2:2 resulted in maximum net returns of ₹ 16,104 ha^{-1} and benefit cost ratio of 1.84, followed by maize- rice bean intercropping in the row proportion of 2:2 (₹ 15,319 ha^{-1} and 1.71, respectively). Anita (2014) revealed that fodder cowpea intercropped with guinea grass cv Harithasree in 1:2 ratio gave higher net income (₹ 2,09,010) and BCR (3.28).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Intercropping fodder legumes in palisade grass (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.) was conducted during June 2017 to March 2018 to evaluate the production potential of intercropping fodder legumes in palisade grass in terms of yield and quality and also to assess the biological and economic efficiency of the intercropping system. The materials and methods adopted for the study are presented in detail in this chapter.

3.1. EXPERIMENTAL SITE

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

3.2. SEASON AND WEATHER CONDITIONS

The field experiment was conducted during the period from June 2017 to March 2018. The data on weather parameters (monthly rainfall, maximum temperature, minimum temperature, relative humidity, evaporation and sunshine hours) during the cropping period were collected from the Agro - Meteorological Observatory at College of Agriculture, Vellayani and is presented in Fig. 1 and Appendix 1.

Table 1. Abstract of the weather data during the experimental period (June 2017 to March 2018)

Weather elements	Range
Maximum temperature (°C)	30.80-33.23
Minimum temperature (°C)	21.79-24.90
Relative humidity (%)	87.62-94.90
Bright sunshine hours	5.20-9.13
Total Rain fall (mm)	1312.6
Monthly evaporation (mm)	3.00- 4.12

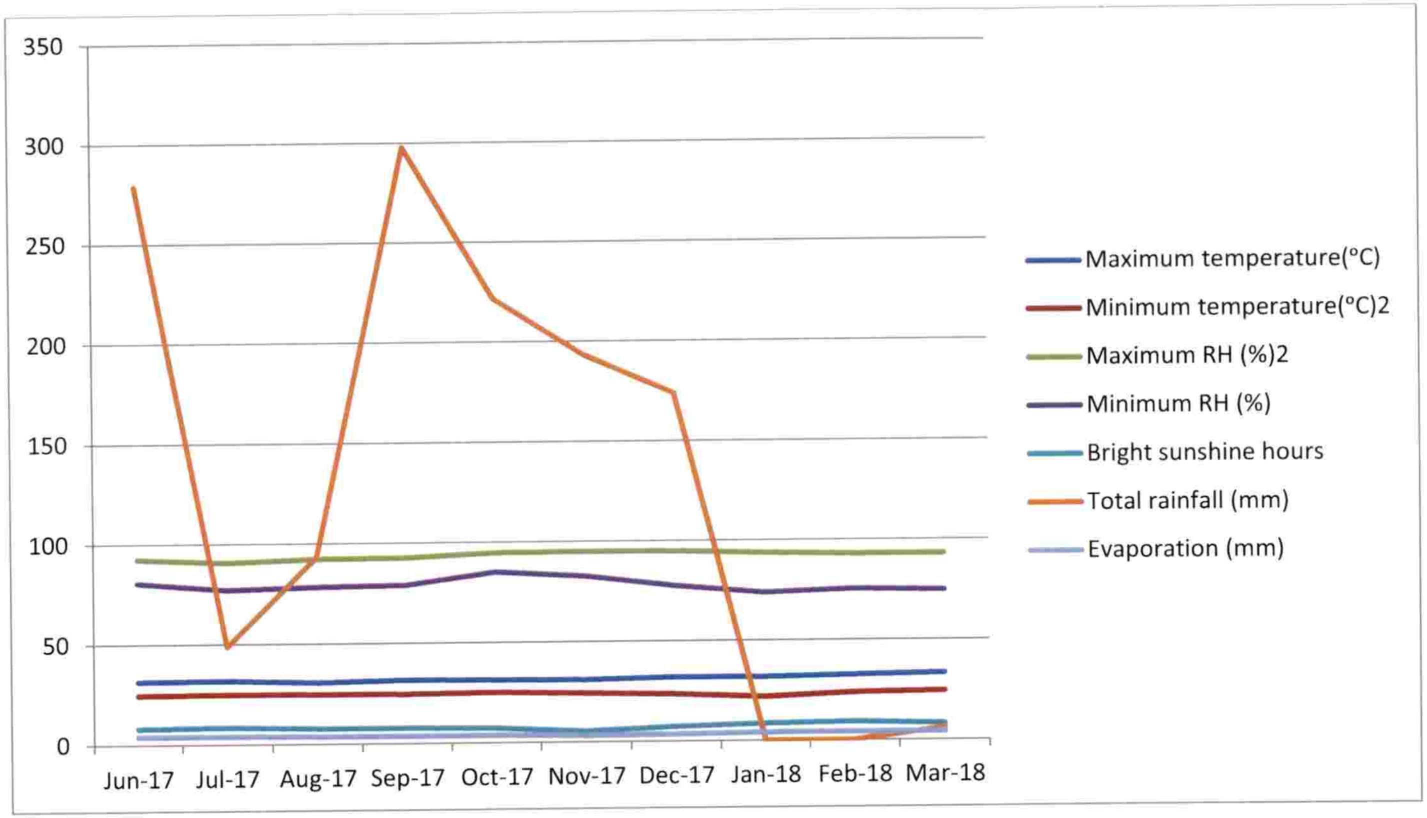

Figure.1 Weather data during June 2017 to March 2018

3.3. SOIL

The soil of the experimental site was red sandy clay loam which belongs to the order oxisols, Vellayani series. The composite soil samples were drawn from 0 - 15 cm depth before conducting the experiment and analyzed for physico - chemical properties. The data obtained is presented in Table 2.

Table 2. Physico-chemical properties of soil in the experimental site

Particulars	**Mean value**	**Method used**
A. Physical properties		
1. Mechanical composition		
Coa rse sand (per cent)	16.92	International pipette method (Piper, 1967)
Fine sand (per cent)	30.52	
Silt (per cent)	23.85	
Clay (per cent)	27.81	
Textural class	Sandy clay loam	
2. Bulk density (Mg m^{-3})	1.45	Core method (Gupta and Dakshinamoorthi, 1980)
3. Water holding capacity (per cent)	30.26	Core method (Gupta and Dakshinamoorthi, 1980)
4. Porosity (per cent)	43	Core method (Gupta and Dakshinamoorthi, 1980)

B. Chemical properties		
1. Soil reaction (pH)	5.20 (strongly acidic)	pH meter with glass electrode (Jackson, 1973)
2.Electrical conductivity ($dS\ m^{-1}$)	0.08 (safe)	Digital conductivity meter (Jackson, 1973)
3. Organic C (%)	0.72 (medium)	Walkley and Black rapid titration method (Jackson, 1973)
4. Available N ($kg\ ha^{-1}$)	280.23 (medium)	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
5. Available P ($kg\ ha^{-1}$)	245.28 (high)	Bray's colorimetric method (Jackson, 1973)
6. Available K ($kg\ ha^{-1}$)	317.29 (high)	Neutral normal ammonium acetate method (Jackson, 1973)

3.4. CROPS AND VARIETIES

3.4.1. Main crop: Palisade grass

Palisade grass (*Brachiaria brizantha*) is a quick growing, high yielding fodder crop best suited to the tropical humid conditions. The crop is very aggressive, resistant to drought, compete effectively with other species and quickly cover the ground. The variety Mulato released from International Centre for Tropical

Agriculture (ICTA) was used for the experiment. It is the first hybrid in Brachiaria genus and obtained from crossing *Brachiaria ruziziensis* (clone 44-6) and *Brachiaria brizantha* (CIAT 6297). The slips for planting were procured from All India Coordinated Research Project on Forage Crops at Vellayani Centre, Thiruvananthapuram, Kerala.

3.4.2. Inter crops: Fodder cowpea and Fodder rice bean

The Fodder cowpea variety CO-9 was used for the study. It is a short duration variety (50-55 days) released from the Department of Forage Crops, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore. The variety is suitable for intercropping with sorghum and maize. The variety has a green fodder yield of 22.82 t ha^{-1} and crude protein content of 21.56%. It is moderately resistant to yellow mosaic virus and resistant to major pests.

Fodder rice bean is considered as an underutilized and neglected fodder legume. It is a palatable and highly nutritious legume rich in protein, calcium and phosphorous. The variety used for the study was Bidhan-2 released from Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, West Bengal. The variety has a green fodder yield of 25 - 30 t ha^{-1}.

3.4.3. Manures and Fertilizers

Farmyard manure (FYM) containing 0.50 per cent N, 0.20 per cent P_2O_5 and 0.40 per cent K_2O was the source of organic manure. The fertilizers used for the study were urea (46 per cent N), rajphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O).

3.5. EXPERIMENTAL DESIGN AND LAY OUT

Design : Randomised Block Design (Factorial)

Season : *Kharif* 2017

Treatments : $3\times3+2 = 11$

Replication: 3

Plot size : 4.8 m x 3.6 m

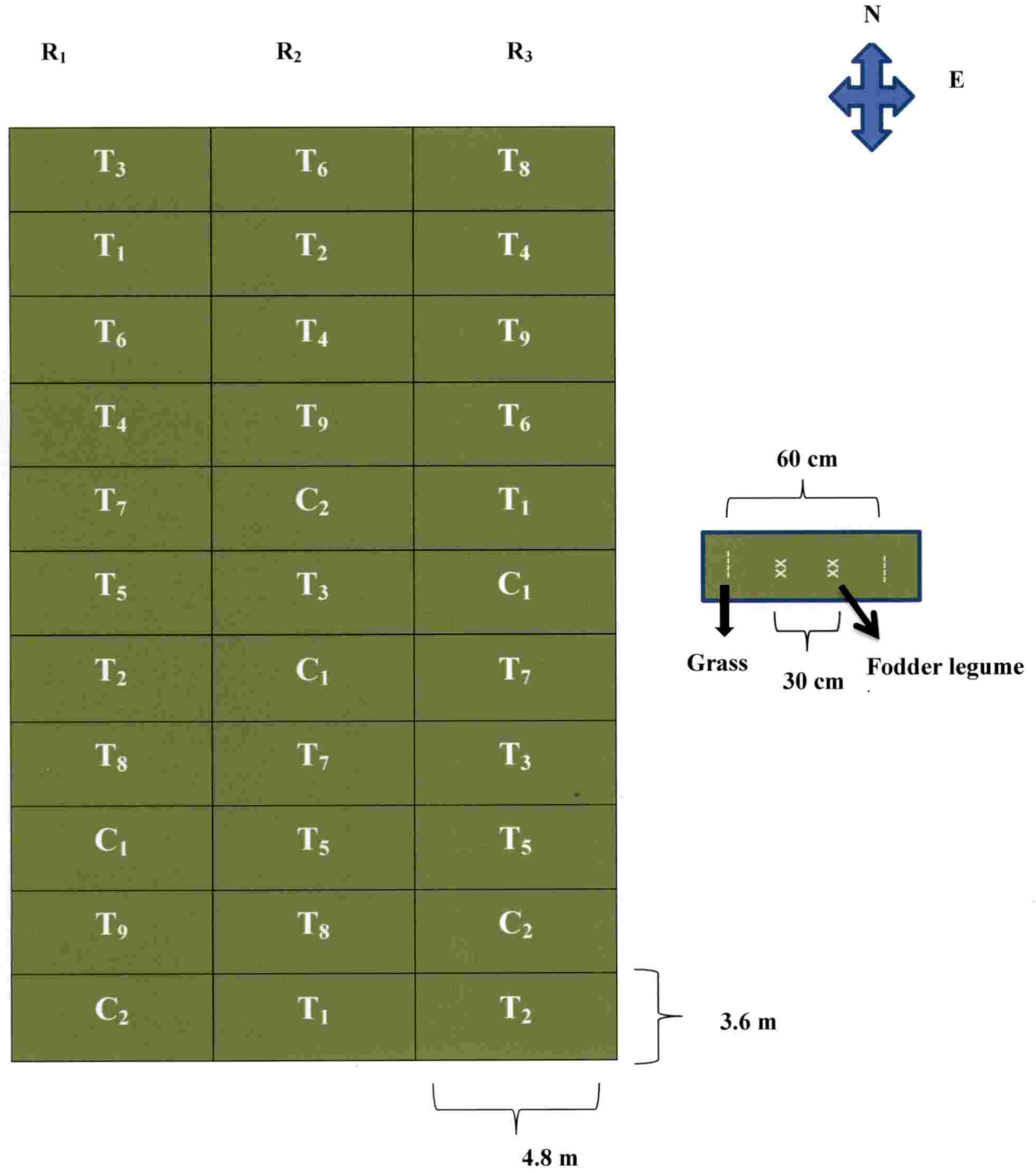

Fig. 2. Lay out of field experiment

Treatments

Main crop: Palisade grass

Inter crops: Fodder cowpea and fodder rice bean

Factor A. Intercropping (I) - 3

i_1- no intercropping

i_2- intercropping with fodder cowpea

i_3- intercropping with fodder rice bean

Factor B. Spacing of main crop (S) - 3

s_1- 60 cm x 30 cm

s_2- 60 cm x 40 cm

s_3- 60 cm x 60 cm

Control (C) – 2

c_1- pure crop of fodder cowpea

c_2- pure crop of fodder rice bean

Treatment combinations

T_1- i_1s_1	T_4 - i_2s_1	T_7 - i_3s_1
T_2 - i_1s_2	T_5 - i_2s_2	T_8 - i_3s_2
T_3 - i_1s_3	T_6 - i_2s_3	T_9 - i_3s_3

3.6. DETAILS OF CULTIVATION

3.6.1. Field Preparation

The experimental area was cleared by removing weeds and stubbles. After thorough ploughing land was divided in to beds.

Plate 1. General view of experimental site

Plate 2. Sole crop of palisade grass

Plate 3. Palisade grass intercropped with fodder cowpea

Plate 4. Palisade grass intercropped with fodder rice bean

3.6.2. Manuring and Fertilizer Application

FYM @ 10 t ha^{-1} was uniformly applied as basal dose to all the treatments. In the treatments involving palisade grass along with fodder legumes and pure crop of palisade grass, N, P and K recommendation @ 300:75:75 kg ha^{-1} (1/2 N, 1/2 P and 1/2 K as basal dose and 1/2 N, 1/2 P and 1/2 K after the second harvest of palisade grass) was applied. For pure crop of fodder legumes (fodder cowpea and fodder rice bean) N, P and K recommendation @ 25: 60:30 kg ha^{-1} was applied as basal dose.

3.6.3. Planting

The planting of healthy slips of palisade grass was done on 6th June 2017 as per the treatments. The fodder legumes were raised two times, *i,e.,* the first crop was sown along with the planting of palisade grass and second crop was sown after the second harvest of palisade grass. Two rows of fodder legumes were sown in between two rows of palisade grass at a spacing of 30 cm x 15 cm.

3.6.4. After Care

Gap filling was done twenty days after planting in palisade grass. In the case of fodder legumes thinning was done one week after planting and uniform population was maintained. Both grass and legumes were grown as rain fed crops. However during summer season irrigation were given at once in two days. Manual weeding was done at monthly intervals.

3.6.5. Harvest

There were four harvests for palisade grass and two harvests each for fodder cowpea and fodder rice bean. The first harvest of the palisade grass was taken at 90 days after planting and subsequent harvests at an interval of 45 days. The fodder cowpea and fodder rice bean were harvested at 50 and 60 days after sowing respectively.

3.7. OBSERVATIONS RECORDED

3.7.1. Biometric Observations (at each harvest)

Five sample plants, each for grass and fodder legumes were randomly selected from the net plot for recording the biometric observations.

3.7.1.1. Plant Height

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

3.7.1.2. Tillers or Branches Plant^{-1}

The number of tillers (palisade grass) and number of branches (fodder legumes) in the sample plants was counted and the average was worked out and recorded.

3.7.1.3. Leaf: Stem Ratio

The sample plants collected at each harvest were separated into stem and leaf. The leaf and stem were separately oven dried at a temperature of 70 ±5 °C to a constant weight, and leaf: stem ratio was calculated as follows.

$$\text{Leaf: stem ratio} = \frac{\text{Dry weight of leaf}}{\text{Dry weight of stem}}$$

3.7.1.4. Leaf Area Index

Leaf area index was calculated before each harvest using the length width method suggested by Gomez (1972) and averages were worked out.

Leaf area = Leaf length x leaf breadth x number of leaves per plant x constant (0.75 for palisade grass, fodder cowpea and 0.60 for rice bean)

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area occupied by the plant}}$$

3.7.2. Yield Parameters

3.7.2.1. Green Fodder Yield at each harvest

The green fodder yield from the net plot area was recorded at each harvest and expressed in t ha^{-1}.

3.7.2.2. Dry Fodder Yield at each harvest

The fresh weight of sample plants collected from each plot were recorded and then the sample plants were then sun dried and later oven dried at a temperature of 70 ±5 °C to a constant weight. The dry fodder yield was computed for each harvest as follows and expressed as t ha^{-1}.

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

3.7.2.3. Total Green Fodder Yield

The total green fodder yield was obtained by summing the green fodder yield per net plot recorded for each harvest and expressed in t ha^{-1}

3.7.2.4. Total Dry Fodder Yield

The total dry fodder yield was computed by summing the dry fodder yield per net plot recorded for each harvest and expressed in t ha^{-1}

3.7.3. Land use efficiency and Biological efficiencies

3.7.3.1. Land Equivalent Ratio (LER)

The LER for intercropped treatments was computed as per the procedure suggested by Mead and Willey (1980).

$$\text{LER} = \frac{\text{Intercrop yield of A}}{\text{Pure crop yield of A}} + \frac{\text{Intercrop yield of B}}{\text{Pure crop yield of B}}$$

Where A (palisade grass) and B (fodder legumes) are component crops.

3.7.3.2. Aggressivity

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

$A_{ab} = \quad Y_{ab} / Y_{aa} Z_{ab} \; - \; Y_{ba} / Y_{bb} Z_{ba}$ Where,

Y_{aa} = pure stand yield of species a

Y_{bb} = pure stand yield of species b

Y_{ab}= mixture yield of species 'a' in combination with 'b'

Y_{ba} = mixture yield of species 'b' in combination with 'a'

Z_{ab}= sown proportion of species 'a' in mixture with 'b'

Z_{ba} = sown proportion of species 'b' in mixture with 'a'

Here 'a' is palisade grass and 'b' is fodder legume

3.7.3.3. Land Equivalent Coefficient (LEC)

LEC was worked out for the mixture plots using the formula suggested by Adetiloye *et al.* (1983).

$LEC = L_A \times L_B$

L_A - LER of palisade grass

L_B - LER of fodder cowpea /fodder rice bean

3.7.3.4. Crop equivalent yield (CEY)

Crop equivalent yield was worked out by converting the yield of intercrops to the equivalent yield of main crop using the crop equivalent factor (Prasad and Srivastava, 1991) and expressed in t ha^{-1}

$$CEY = \text{Yield of fodder legumes} \times \frac{\text{Market price of unit weight of fodder legumes}}{\text{Market price of unit weight of grass}}$$

3.7.4. Quality Studies (at final harvest)

3.7.4.1. Crude Protein Content

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

3.7.4.2. Crude protein yield

Crude protein yield was calculated by multiplying the crude protein content in plant and dry matter production and expressed in t ha^{-1}.

3.7.4.3. Crude Fibre Content

Crude fibre content at final harvest was determined by A. O. A. C. method (A. O. A. C., 1975) and expressed in percentage.

3.7.5. Plant Analysis

3.7.5.1. Uptake of Nitrogen

The nitrogen content in plant was estimated by modified micro Kjeldal method (Jackson, 1973) and based on the nitrogen content and the dry matter produced the uptake of nitrogen was calculated and expressed in kg ha^{-1}.

3.7.5.2. Uptake of Phosphorus

Vanedo-molybdate yellow colour method was used for estimation of phosphorus content using spectrophotometer (Jackson, 1973) and phosphorus uptake was calculated from the phosphorus content and dry matter produced and expressed in kg ha^{-1}.

3.7.5.3. Uptake of Potassium

The potassium content was estimated using flame photometer (Jackson, 1973). The uptake of potassium was calculated from the potassium content and dry matter produced and expressed in kg ha^{-1}.

3.7.6. Soil Analysis Before and After the Experiment

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).

3.7.7. Economic Analysis

The economics of cultivation was worked out based on the cost of cultivation and prevailing market price of the fodder crops.

3.7.7.1. Net Income

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

3.7.7.2. B: C Ratio

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

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

3.7.8. Statistical Analysis

The data pertaining to each observation was analysed statistically by applying the analysis of variance technique (ANOVA) as suggested by Panse and Sukhatme, 1985. Wherever significant differences among treatments were observed, CD values at 5 per cent level of significance were calculated for comparison of means.

RESULTS

4. RESULTS

The present experiment entitled "Intercropping fodder legumes in palisade grass (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.)" was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani during June 2017 to March 2018 to evaluate the production potential of intercropping fodder legumes in palisade grass in terms of yield and quality and also to assess the biological and economic efficiency of the intercropping system. The experimental data collected were analysed statistically and the results are presented below.

4.1. BIOMETRIC OBSERVATIONS

4.1.1. Plant Height

The result of the effect of the treatments (intercropping and plant spacing) with respect to plant height of palisade grass, fodder cowpea and fodder rice bean are presented in Table 3a.and 3b.

The results revealed that intercropping had significant impact on plant height of palisade grass in all harvests. In the first harvest, significantly higher plant height was recorded by intercropping palisade grass with fodder rice bean (121.81 cm). However in the second and third harvest, highest plant height was observed with pure crop of palisade grass (94.33 and 98.75 cm) and it was found to be on par with intercropping with rice bean in the second harvest (91.91 cm) and intercropping with fodder cowpea in the third harvest (96.19 cm). But in the fourth harvest, intercropping with rice bean was on par with pure crop of palisade grass and significantly superior to intercropping with fodder cowpea.

The height of palisade grass was significantly influenced by different spacing treatments in all harvests. Among the spacing treatments, significantly higher plant height was registered by narrow spacing of 60 cm x 30 cm in first (124.30cm) and fourth harvest (34.61cm) whereas spacing treatments of 60 cm x 30 cm and 60 cm x 40 cm were found to be on par in second and third harvest. In all the harvests wider spacing (60 cm x 60 cm) recorded lower plant height in palisade grass.

Among the treatment combinations, no significant interaction was observed between intercropping and plant spacing in any of the harvest.

Regarding fodder cowpea and fodder rice bean, the treatments had no significant influence on plant height during both crops.

Table 3.a Effect of intercropping, spacing and their interaction on plant height of palisade grass, cm

Treatments	Plant height (cm)			
	Harvest I	Harvest II	Harvest III	Harvest IV
Intercropping (I)				
I_1	117.68	94.33	98.75	32.47
I_2	112.37	86.52	96.19	30.91
I_3	121.81	91.91	85.00	32.75
SEm (±)	1.187	1.131	1.499	0.459
CD (0.05)	3.576	3.398	4.491	1.382
Spacing (S)				
S_1	124.30	95.08	96.77	34.61
S_2	115.99	91.94	95.61	31.47
S_3	111.57	85.75	87.55	30.05
SEm (±)	1.187	1.131	1.499	0.459
CD (0.05)	3.576	3.398	4.491	1.382
Intercropping × spacing (I×S)				
i_1 s_1	123.63	99.25	102.50	33.83
i_1 s_2	116.41	97.00	100.75	32.16
i_1 s_3	113.00	86.75	93.00	31.41
i_2 s_1	121.33	91.50	94.83	34.00
i_2 s_2	111.63	86.08	100.75	29.75
i_2 s_3	104.15	82.00	93.00	29.00
i_3 s_1	127.95	94.50	93.00	36.00
i_3 s_2	119.92	92.75	85.33	32.50
i_3 s_3	117.58	88.50	76.66	29.75
SEm (±)	2.057	1.958	2.595	0.791
CD (0.05)	NS	NS	NS	NS

Table 3.b Effect of intercropping and spacing on plant height of fodder cowpea and fodder rice bean, cm

Treatments	**1^{st} crop**	**2^{nd} crop**
Fodder Cowpea		
T_4 - i_2s_1	122.83	73.83
T_5 - i_2s_2	139.00	70.83
T_6 - i_2s_3	151.66	69.33
C_1	143.16	71.50
SEm (±)	2.184	9.673
CD (0.05)	NS	NS
Fodder Rice bean		
T_7 - i_3s_1	121.66	66.00
T_8 - i_3s_2	126.66	59.33
T_9 - i_3s_3	105.00	61.33
C_2	109.33	57.33
SEm (±)	11.045	3.238
CD (0.05)	NS	NS

4.1.2. No of tillers / branches plant^{-1}

The data on number of tillers / branches plant^{-1} of palisade grass, fodder cow pea and fodder rice bean are furnished in Table 4a.and 4b.

Significant effect of intercropping on number of tillers plant^{-1} was noticed only during the first and second harvests. In the first harvest, significantly higher number of tillers was registered by pure crop of palisade grass (66.4) whereas in the second harvest, highest number of tillers was observed in intercropping palisade grass with rice bean (42.88) and it was found to be on par with sole crop of palisade grass (40.44). However in both harvests lowest number of tillers was observed with intercropping palisade grass with fodder cowpea.

Significant effect of spacing on number of tillers plant^{-1} was noticed in all harvests except first harvest. In the later harvests, highest number of tillers was recorded by wider spacing of 60 cm x 60 cm and it was on par with S_2 (60cm × 40 cm). The lower number of tillers per plant was recorded with 60 cm x 30 cm spacing in second harvest and it was found to be on par with 60 cm x 40 cm spacing in third and fourth harvest.

Among the treatment combinations, no significant interaction was observed between intercropping and plant spacing in any of the harvest.

The treatments had no significant effect on number of branches in the first crop of fodder cowpea. In the second crop of fodder cowpea, pure crop of fodder cowpea recorded highest number of branches (3.00). All intercropping treatments recorded equal number of branches plant^{-1}.

Regarding fodder rice bean, the treatments had no significant influence on number of branches in both crops.

Table 4.a Effect of intercropping, spacing and their interaction on number of tillers plant^{-1} of palisade grass

Treatments	**No of tillers plant^{-1}**			
	Harvest I	**Harvest II**	**Harvest III**	**Harvest IV**
Intercropping(I)				
I_1	66.44	40.44	60.66	26.00
I_2	55.11	35.22	57.88	24.11
I_3	55.22	42.88	62.22	25.00
SEm(±)	2.050	1.053	1.520	1.216
CD(0.05)	6.164	3.170	NS	NS
Spacing(S)				
S_1	56.33	36.22	57.00	22.00
S_2	59.33	40.11	60.00	25.00
S_3	61.11	42.22	63.77	28.11
SEm(±)	2.050	1.053	1.520	1.216
CD(0.05)	NS	3.170	4.560	3.654
Intercropping × spacing (I×S)				
i_1 s_1	63.00	36.33	58.33	23.66
i_1 s_2	66.00	41.00	59.66	26.33
i_1 s_3	70.33	44.00	64.00	28.00
i_2 s_1	51.66	34.00	54.00	21.00
i_2 s_2	54.66	35.66	58.33	23.66
i_2 s_3	59.00	36.00	61.33	27.66
i_3 s_1	54.33	38.33	58.66	21.33
i_3 s_2	57.33	43.66	62.00	25.00
i_3 s_3	54.00	46.66	66.00	28.66
SEm(±)	3.556	1.831	2.637	2.107
CD(0.05)	NS	NS	NS	NS

Table 4.b Effect of intercropping and spacing on branches plant^{-1} of fodder cowpea and fodder rice bean

Treatments	1st crop	2nd crop
Fodder cowpea		
T_4 - i_2s_1	2.00	1.00
T_5 - i_2s_2	1.83	1.00
T_6 - i_2s_3	2.00	1.00
C_1	1.83	3.00
SEm(±)	0.757	0.538
CD(0.05)	NS	1.325
Fodder rice bean		
T_7 - i_3s_1	3.33	1.33
T_8 - i_3s_2	5.00	1.33
T_9 - i_3s_3	4.66	1.66
C_2	5.66	2.00
SEm(±)	0.652	0.303
CD(0.05)	NS	NS

4.1.3. Leaf: stem ratio

Data pertaining to leaf: stem ratio of palisade grass, fodder cowpea and fodder rice bean are presented in Table 5a.and 5b.

Though highest leaf: stem ratio was obtained by pure stand of palisade grass in first and fourth harvests (1.30 and 2.08), it was found to be on par with intercropping palisade grass with fodder rice bean (1.15) in first harvest and intercropping palisade grass with fodder cowpea(1.82) in the fourth harvest. Significantly higher leaf: stem ratio of 3.21 was registered with intercropping palisade grass with fodder rice bean in second harvest.

The result revealed that different spacing treatments did not show any significant influence on leaf: stem ratio of palisade grass.

Similarly, different treatment combinations had no significant effect on leaf: stem ratio.

The treatments had no significant effect on leaf: stem ratio in first crop of fodder cowpea. Whereas in the second crop, highest leaf: stem ratio was registered by pure crop of fodder cowpea (0.866) and it was found to be on par with T_5

Regarding fodder rice bean significantly higher leaf: stem ratio was recorded by pure crop of rice bean in both crops (1.44 and 0.816), followed by T_9, T_8, and T_7 in both crops.

Table 5.a Effect of intercropping, spacing and their interaction on leaf: stem ratio of palisade grass

Treatments	Leaf :stem ratio			
	Harvest I	Harvest II	Harvest III	Harvest IV
Intercropping(I)				
I_1	1.30	2.13	3.70	2.08
I_2	0.91	2.22	4.86	1.82
I_3	1.15	3.21	4.10	1.36
SEm(±)	0.057	0.204	0.543	0.079
CD(0.05)	0.186	0.616	NS	0.224
Spacing(S)				
S_1	1.21	2.53	4.85	1.64
S_2	1.06	2.81	3.13	1.75
S_3	1.09	2.21	4.67	1.87
SEm(±)	0.057	0.204	0.543	0.079
CD(0.05)	NS	NS	NS	NS
Intercropping × spacing (I×S)				
i_1 s_1	1.45	1.76	3.72	2.14
i_1 s_2	1.19	2.71	2.82	2.07
i_1 s_3	1.27	1.94	4.56	2.03
i_2 s_1	0.996	2.76	7.25	1.44
i_2 s_2	0.843	2.55	3.85	1.87
i_2 s_3	0.903	1.34	3.48	2.15
i_3 s_1	1.19	3.09	3.59	1.35
i_3 s_2	1.16	3.16	2.72	1.30
i_3 s_3	1.11	3.37	5.98	1.42
SEm(±)	0.099	0.354	0.940	0.137
CD(0.05)	NS	NS	NS	NS

Table 5.b Effect of intercropping and spacing on leaf: stem ratio of fodder cowpea and fodder rice bean,

Treatments	**1^{st} crop**	**2^{nd} crop**
Fodder cowpea		
T_4 - i_2s_1	0.853	0.553
T_5 - i_2s_2	1.02	0.706
T_6 - i_2s_3	0.823	0.670
C_1	0.693	0.866
SEm($\pm$)	0.159	0.040
CD(0.05)	NS	0.170
Fodder rice bean		
T_7 - i_3s_1	0.633	0.306
T_8 - i_3s_2	0.723	0.350
T_9 - i_3s_3	0.870	0.516
C_2	1.44	0.816
SEm($\pm$)	0.074	0.031
CD(0.05)	0.205	0.119

4.1.4. Leaf area index

Data pertaining to leaf area index of palisade grass, fodder cowpea and fodder rice bean are furnished in Table 6a.and 6b.

Intercropping treatments had no significant effect on leaf area index of palisade grass.

The leaf area index of palisade grass was significantly influenced by different spacing treatments in all harvests. In first, third and fourth harvests highest leaf area index was recorded by narrow spacing S_1 (60 cm × 30 cm). Whereas in second harvest, highest leaf area index was observed with S_2 (60 cm × 40 cm) and it was found to be on par with S_1 (60 cm × 30 cm).

Among the treatment combinations, no significant interaction was observed between intercropping and plant spacing in all harvests.

Treatments had no significant effect on leaf area index of fodder cowpea in first crop. But in the second crop, significantly higher leaf area index was obtained by pure stand of fodder cowpea (8.99). The LAI recorded under all the spacing treatments were on par.

Regarding fodder rice bean highest leaf area index was observed with pure crop of rice bean (4.13 and 2.06) in both crops, followed by T_9 (60 cm × 60 cm), T_8 (60 cm × 40 cm) and T_7 (60 cm × 30 cm) in both crops.

Table 6.a Effect of intercropping, spacing and their interaction on leaf area index of palisade grass

Treatments	Leaf area index			
	Harvest I	Harvest II	Harvest III	Harvest IV
Intercropping(I)				
I_1	7.21	2.82	4.08	0.607
I_2	7.89	2.32	4.740	0.465
I_3	6.47	2.86	4.146	0.564
SEm(±)	0.443	0.278	0.260	0.052
CD(0.05)	NS	NS	NS	NS
Spacing(S)				
S_1	9.23	2.73	5.34	0.688
S_2	6.84	3.19	4.39	0.486
S_3	5.50	2.07	3.23	0.462
SEm(±)	0.443	0.278	0.260	0.052
CD(0.05)	1.339	0.832	0.787	0.154
Intercropping × spacing (I×S)				
i_1 s_1	8.52	2.52	5.03	0.810
i_1 s_2	7.16	3.93	3.65	0.563
i_1 s_3	5.94	2.02	3.57	0.450
i_2 s_1	9.69	2.83	5.54	0.740
i_2 s_2	7.45	2.49	5.42	0.340
i_2 s_3	6.53	1.63	3.25	0.316
i_3 s_1	9.50	2.84	5.47	0.516
i_3 s_2	5.90	3.16	4.10	0.556
i_3 s_3	4.03	2.58	2.87	0.620
SEm(±)	0.763	0.482	0.451	0.091
CD(0.05)	NS	NS	NS	NS

Table 6.b Effect of intercropping and spacing on leaf area index of fodder cowpea and fodder rice bean

Treatments	1^{st} crop	2^{nd} crop
Fodder cowpea		
T_4 - i_2s_1	7.72	1.24
T_5 - i_2s_2	7.05	1.83
T_6 - i_2s_3	5.90	1.60
C_1	6.73	8.99
SEm(±)	1.067	0.193
CD(0.05)	NS	0.683
Fodder rice bean		
T_7 - i_3s_1	2.68	1.45
T_8 - i_3s_2	3.18	1.59
T_9 - i_3s_3	3.59	1.79
C_2	4.13	2.06
SEm(±)	0.123	0.025
CD(0.05)	0.423	0.170

4.2. YIELD PARAMETERES

4.2.1. Green fodder yield

The data on green fodder yield of palisade grass, fodder cowpea and fodder rice bean are presented in Table 7a.and 7b.

The result showed that intercropping had significant effect on green fodder yield of palisade grass in first, third and fourth harvests. In all harvests, highest green fodder yield was recorded by sole crop of palisade grass (91.28, 48.83 and 8.20 t ha^{-1} respectively) and was found to be on par with intercropping with fodder cowpea in third and fourth harvest. With respect to total green fodder yield, significantly highest yield was observed with sole crop of palisade grass (169.56 t ha^{-1}) followed by intercropping with fodder rice bean (129.30 t ha^{-1}) and intercropping with fodder cowpea (102.32 t ha^{-1}).

Significant effect of spacing treatments on green fodder yield was observed only on the first harvest. In the first harvest, significantly highest green fodder yield was recorded by narrow spacing of 60 cm ×30 cm. Spacing treatments had no significant effect on total green fodder yield of palisade grass.

Among the treatment combinations, no significant interaction was observed between intercropping and plant spacing in all harvests.

With respect to fodder cowpea, significant effect of treatments on green fodder yield was observed in second crop. In the second crop, significantly higher green fodder yield was registered by pure crop of fodder cowpea (10.41 t ha^{-1}). The intercropping treatments at all spacing were found to be on par. The total green fodder yield was found to be non-significant.

Regarding fodder rice bean, significantly higher green fodder yield was obtained with pure crop of fodder rice bean compared to intercropped treatments in individual fodder yield as well as in total fodder yield.

Table 7.a Effect of intercropping, spacing and their interaction on green fodder yield of palisade grass, t ha^{-1}

Treatments	Green fodder yield (t ha^{-1})				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
Intercropping(I)					
I_1	91.28	21.02	48.83	8.20	169.56
I_2	31.06	18.52	45.45	7.28	102.32
I_3	59.67	24.83	38.50	6.56	129.30
SEm(±)	3.323	1.788	2.241	0.409	5.572
CD(0.05)	9.970	NS	6.740	1.220	16.714
Spacing(S)					
S_1	70.32	22.54	43.83	6.99	143.67
S_2	57.86	22.98	41.43	6.94	129.23
S_3	53.82	18.85	47.52	8.11	128.28
SEm(±)	3.323	1.788	2.241	0.409	5.572
CD(0.05)	9.970	NS	NS	NS	NS
Intercropping × spacing (I×S)					
$i_1 s_1$	102.50	20.43	47.08	8.83	178.84
$i_1 s_2$	84.16	23.88	45.41	7.99	161.45
$i_1 s_3$	87.18	18.75	54.00	7.80	168.39
$i_2 s_1$	35.55	23.88	48.73	6.83	114.99
$i_2 s_2$	27.77	18.74	40.55	6.69	93.76
$i_2 s_3$	29.85	12.94	47.08	8.33	98.21
$i_3 s_1$	72.91	23.33	35.69	5.33	137.18
$i_3 s_2$	61.66	26.33	38.33	6.16	132.48
$i_3 s_3$	44.44	24.85	41.50	8.20	118.24
SEm(±)	5.755	3.097	3.889	0.707	9.652
CD(0.05)	NS	NS	NS	NS	NS

Table 7.b Effect of intercropping and spacing on green fodder yield of fodder cowpea and fodder rice bean, t ha^{-1}

Treatments	1^{st} crop	2^{nd} crop	Total
Fodder cowpea			
T_4 - i_2s_1	27.35	2.22	29.57
T_5 - i_2s_2	30.41	3.19	33.60
T_6 - i_2s_3	27.63	2.77	30.41
C_1	27.76	10.41	38.18
SEm(±)	2.31	1.364	2.269
CD(0.05)	NS	4.733	NS
Fodder rice bean			
T_7 - i_3s_1	6.24	3.12	9.36
T_8 - i_3s_2	6.80	3.40	10.20
T_9 - i_3s_3	8.33	4.16	12.49
C_2	17.2	9.43	26.63
SEm(±)	1.527	0.763	1.272
CD(0.05)	5.293	2.650	4.425

4.2.2. Dry fodder yield

Table 8a.and 8b. shows the effect of treatments on the dry fodder yield of palisade grass, fodder cowpea and fodder rice bean.

The dry fodder yield of palisade grass was significantly influenced by intercropping treatments in first, third and fourth harvests. In all harvests, highest dry fodder yield was registered by pure crop of palisade grass (16.5 t ha^{-1}, 10.16 t ha^{-1} and 1.63 t ha^{-1}) and it was found to be on par with intercropping palisade grass with fodder cowpea in third and fourth harvest. With respect to total dry fodder yield, significantly higher yield was observed with pure crop of palisade grass (32.95 t ha^{-1})

Significant influence of spacing treatments on dry fodder yield was observed only on the first harvest. In the first harvest, highest dry fodder yield (13.11 t ha^{-1}) was recorded by narrow spacing S_1 (60 cm ×30 cm) which was on par with S_2 (60 cm × 40 cm). However spacing treatments had no significant effect on total dry fodder yield of palisade grass.

Among the treatment combinations, no significant interaction was observed between intercropping and plant spacing in all harvests.

With respect to fodder cowpea, dry fodder yield was significantly influenced by treatments in second crop only. In the second crop, highest dry fodder yield was registered by pure stand of fodder cowpea (2.08 t ha^{-1}). But the total yield was found to be non-significant.

Regarding fodder rice bean, dry fodder yield was significantly higher in pure stand of fodder rice bean compared to intercropped treatments in both crops. Similarly, total dry fodder yield was also significantly higher for pure crop of rice bean (5.15 t ha^{-1}).

Table 8.a Effect of intercropping, spacing and their interaction on dry fodder yield of palisade grass, t ha^{-1}

Treatments	Dry fodder yield (t ha^{-1})				
	Harvest I	Harvest II	Harvest III	Harvest IV	Total
Intercropping(I)					
I_1	16.50	4.18	10.16	1.63	32.95
I_2	6.29	3.69	9.22	1.45	20.66
I	11.58	4.80	7.24	1.26	25.29
SEm(±)	0.728	0.377	0.478	0.085	0.933
CD(0.05)	2.190	NS	1.430	0.242	2.815
Spacing(S)					
S_1	13.11	4.50	8.70	1.40	27.79
S_2	10.97	4.44	8.12	1.38	25.73
S_3	10.27	3.74	9.80	1.56	25.39
SEm(±)	0.728	0.377	0.478	0.085	0.933
CD(0.05)	2.190	NS	NS	NS	NS
Intercropping × spacing (I×S)					
$i_1\ s_1$	19.40	4.08	9.41	1.76	33.16
$i_1\ s_2$	13.95	4.77	10.16	1.59	33.36
$i_1\ s_3$	16.16	3.70	10.93	1.56	32.35
$i_2\ s_1$	7.10	4.76	9.74	1.37	22.97
$i_2\ s_2$	5.80	3.74	7.79	1.33	18.66
$i_2\ s_3$	5.96	2.58	10.14	1.66	20.35
$i_3\ s_1$	12.85	4.66	6.95	1.06	27.24
$i_3\ s_2$	13.18	4.82	6.43	1.23	25.16
$i_3\ s_3$	8.70	4.94	8.34	1.48	23.48
SEm(±)	1.265	0.654	0.827	0.147	1.626
CD(0.05)	NS	NS	NS	NS	NS

Table 8.b Effect of intercropping and spacing on dry fodder yield of fodder cowpea and fodder rice bean, t ha^{-1}

Treatments	1^{st} crop	2^{nd} crop	Total
Fodder cowpea			
T_4 - i_2s_1	5.38	0.443	5.88
T_5 - i_2s_2	6.07	0.646	6.72
T_6 - i_2s_3	5.40	0.570	5.94
C_1	5.49	2.08	7.41
SEm(±)	0.410	0.275	0.383
CD(0.05)	NS	0.951	NS
Fodder rice bean			
T_7 - i_3s_1	1.29	0.620	1.91
T_8 - i_3s_2	1.29	0.676	1.97
T_9 - i_3s_3	1.67	0.830	2.50
C_2	3.66	1.496	5.15
SEm(±)	0.271	0.048	0.240
CD(0.05)	0.942	0.179	0.822

4.2.3. Total green fodder yield and dry fodder yield of the intercropping system

The result of the effect of treatments on total green fodder yield and dry fodder yield of the intercropping system are presented in Table 9.

The total green fodder yield of the system was significantly improved by intercropping. Among the intercropping treatments, significantly higher total green fodder yield was recorded by pure crop of palisade grass (169.56 t ha^{-1}).

However spacing had no significant effect on total green fodder yield of the system

Among the treatment combinations, no significant interaction was observed between intercropping and plant spacing in all harvests

Intercropping had significant effect on total dry fodder yield of the system. Among the intercropping treatments maximum dry fodder yield was recorded by pure crop of palisade grass (32.95 t ha^{-1}).

Spacing treatments had no significant effect on total dry fodder yield of the system

Similarly, the total dry fodder yield of the system was unaffected by treatment combinations.

Table 9. Effect of intercropping, spacing and their interaction on total green fodder yield and dry fodder yield of the intercropping system, t ha^{-1}

Treatments	Total green fodder yield ($t\ ha^{-1}$)	Total dry fodder yield ($t\ ha^{-1}$)
Intercropping(I)		
I_1	169.56	32.95
I_2	133.52	26.84
I_3	142.19	27.84
SEm(±)	5.635	0.926
CD(0.05)	16.901	2.780
Spacing(S)		
S_1	156.68	30.35
S_2	143.83	28.70
S_3	144.76	28.59
SEm(±)	5.635	0.926
CD(0.05)	NS	NS
Intercropping × spacing (I×S)		
$i_1\ s_1$	178.84	33.16
$i_1\ s_2$	161.45	33.36
$i_1\ s_3$	168.39	32.35
$i_2\ s_1$	144.57	28.85
$i_2\ s_2$	127.36	25.39
$i_2\ s_3$	128.62	26.29
$i_3\ s_1$	146.62	29.03
$i_3\ s_2$	142.68	27.36
$i_3\ s_3$	137.27	27.14
SEm(±)	9.765	1.605
CD(0.05)	NS	NS

4.3. LAND USE EFFICIENCY AND BIOLOGICAL EFFICIENCY

The data pertaining to LER, LEC, Aggressivity and CEY of the intercropping system are presented in Table 10a. and 10b.

4.3.1. Land Equivalent Ratio (LER)

The total LER of the intercropping cropping system was significantly influenced by the treatments. Among the treatments, highest LER (1.42) was recorded by T_4 (intercropping palisade grass with fodder cowpea+ 60 cm × 30 cm) and it was found to be on par with T_6 (intercropping palisade grass with fodder cowpea+ 60 cm× 60 cm) and T_5 (intercropping palisade grass with fodder cowpea+ 60 cm× 40 cm). The lowest LER was recorded with T_7 and T_9 and was on par with T_8.

4.3.2. Land Equivalent Coefficient (LEC)

Land equivalent coefficient was also found to be significantly influenced by the treatment combinations. The highest LEC (0.506) was registered by T_4 (intercropping palisade grass with fodder cowpea+ 60 cm × 30 cm) and it was found to be on par with T_6 (intercropping palisade grass with fodder cowpea+ 60 cm × 60 cm) and T_5 (intercropping palisade grass with fodder cowpea+ 60 cm × 40 cm). The lowest LEC was recorded with T_7 and was found to be on par with T_9 and T_8.

4.3.3. Aggressivity

The results indicated that there was significant difference in the aggressivity of palisade grass and fodder legumes between the treatments. Among the treatments, T_8 (intercropping palisade grass with fodder rice bean+ 60 cm × 40 cm) registered highest aggressivity index of 1.43 and was on par with T_7.

4.3.4. Crop Equivalent Yield (CEY)

Crop equivalent yield was significantly increased by treatments. The highest crop equivalent yield of 188.93 t ha^{-1} was recorded by T_4 (intercropping palisade grass with fodder cowpea+ 60 cm × 30 cm) and it was found to be on par with all the treatments from T_1 to T_7.

Table 10. a Effect of intercropping and spacing on LER, LEC and Aggressivity of the intercropping system

Treatments	Land Equivalent Ratio (LER)	Land Equivalent Coefficient (LEC)	Aggressivity	
			Fodder grass	Fodder legumes
T_1- i_1s_1	1.00	-		
T_2 - i_1s_2	1.00	-	-	
T_3 - i_1s_3	1.00	-	-	
T_4- i_2s_1	1.42	0.506	-0.896	0.896
T_5 - i_2s_2	1.36	0.443	-0.723	0.723
T_6 - i_2s_3	1.37	0.453	-0.768	0.768
T_7 - i_3s_1	1.13	0.283	1.34	-1.34
T_8 - i_3s_2	1.24	0.346	1.43	-1.43
T_9 - i_3s_3	1.13	0.306	1.11	-1.11
SEm(±)	0.031	0.031	0.098	
CD(0.05)	0.172	0.106	0.291	

Table 10.b Effect of intercropping and spacing on crop equivalent yield of intercropping system, t ha^{-1}

Treatments	Crop Equivalent Yield (t ha^{-1})
T_1- i_1s_1	178.84
T_2 - i_1s_2	161.45
T_3 - i_1s_3	168.39
T_4- i_2s_1	188.93
T_5 - i_2s_2	177.77
T_6 - i_2s_3	174.24
T_7 - i_3s_1	160.59
T_8 - i_3s_2	157.99
T_9 - i_3s_3	152.22
C_1	95.45
C_2	63.50
SEm(±)	10.37
CD(0.05)	30.610

4.4. QUALITY PARAMETERS

The result of the effect of treatments on crude protein content, crude protein yield, and crude fibre content of palisade grass, fodder cowpea and fodder rice bean and total crude protein yield of the intercropping system are furnished in Table 11a, 11b and 11c.

4.4.1. Crude protein content

The Intercropping treatments had significant improvement on crude protein content of palisade grass. Intercropping palisade grass with fodder cowpea (I_2) recorded the highest crude protein content of 8.53 per cent and it was found to be on par with intercropping palisade grass with fodder rice bean (I_3).

But the spacing treatments had no significant effect on crude protein content of palisade grass.

Among the treatment combinations, maximum crude protein content was registered by i_2 s_1 (intercropping palisade grass with fodder cowpea+60 cm×30 cm) and it was found to be on par with i_3 s_2 (intercropping palisade grass with fodder rice bean+60 cm× 40 cm), i_2 s_2 (intercropping palisade grass with fodder cowpea+60 cm× 40 cm) and i_2 s_3 (intercropping palisade grass with fodder cowpea+60 cm× 60 cm).

The treatments had no significant influence on the crude protein content of fodder cowpea and fodder rice bean.

4.4.2. Crude protein yield

The crude protein yield of palisade grass was significantly improved by intercropping treatments. Among the treatments, significantly higher crude protein yield was registered by pure crop of palisade grass (2.42 t ha^{-1}).

The spacing treatments had no significant effect on crude protein yield of palisade grass.

Among the treatment combinations, maximum crude protein yield was registered by i_1 s_2 (pure crop of palisade grass +60 cm×40 cm) and it was found to be on par with i_1 s_3 (pure crop of palisade grass +60 cm× 60 cm).

The treatments had significant effect on crude protein yield of second crop of fodder cowpea. Among the treatments, maximum crude protein yield was recorded by pure crop of fodder cowpea (0.263 t ha^{-1})

In the case of fodder rice bean, maximum crude protein yield was observed with pure crop of fodder rice bean in both harvests.

4.4.3. Crude fibre content

The crude fibre content of palisade grass was unaffected by both intercropping and spacing treatments. Similarly, the treatment combinations were also found to be non significant.

Likewise in both fodder cowpea and fodder rice bean, the treatments had no significant influence on crude fibre content in both crops.

4.4.4. Total crude protein yield of the system

The results showed that intercropping had significant effect on total crude protein yield of the system. Among the treatments, intercropping palisade grass with fodder cowpea registered significantly higher crude protein yield of 2.67 t ha^{-1}. But the spacing treatments had no significant effect on crude protein yield of the system.

The treatment combinations were also found to be non-significant.

Table 11.a Effect of intercropping, spacing and their interaction on crude protein content, crude protein yield and crude fibre content of palisade grass

Treatments	**Crude protein content(Per cent)**	**Crude protein yield (t ha^{-1})**	**Crude fibre content (per cent)**
Intercropping(I)			
I_1	7.39	2.42	27.35
I_2	8.53	1.73	27.65
I_3	8.41	2.07	27.32
SEm(±)	0.049	0.040	0.287
CD(0.05)	0.160	0.105	NS
Spacing(S)			
S_1	8.06	2.06	27.15
S_2	8.16	2.08	27.64
S_3	8.11	2.08	27.52
SEm(±)	0.049	0.040	0.287
CD(0.05)	NS	NS	NS
Intercropping × spacing (I×S)			
i_1 s_1	7.15	2.31	27.16
i_1 s_2	7.54	2.50	27.28
i_1 s_3	7.50	2.44	27.62
i_2 s_1	8.71	1.90	27.26
i_2 s_2	8.45	1.59	27.81
i_2 s_3	8.43	1.73	27.89
i_3 s_1	8.34	1.98	27.05
i_3 s_2	8.50	2.16	27.85
i_3 s_3	8.40	2.09	27.06
SEm(±)	0.085	0.070	0.497
CD(0.05)	0.288	0.183	NS

Table 11.b Effect of intercropping and spacing on crude protein content, crude protein yield and crude fibre content of fodder cowpea and fodder rice bean

Treatments	Crude protein content (Per cent)		Crude protein yield (t ha^{-1})		Crude fibre content (Per cent)	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Fodder cowpea						
T_4- i_2s_1	15.73	15.97	0.803	0.083	24.15	24.16
T_5 - i_2s_2	15.80	15.77	0.938	0.073	24.32	24.25
T_6 - i_2s_3	15.70	16.08	0.813	0.124	24.29	24.14
C_1	16.13	16.21	0.896	0.263	24.19	24.17
SEm(±)	0.233	0.119	0.040	0.051	0.101	0.085
CD(0.05)	NS	NS	NS	0.083	NS	NS
Fodder rice bean						
T_7- i_3s_1	15.46	15.29	0.186	0.063	25.11	25.13
T_8 – i_3s_2	15.81	15.34	0.217	0.071	25.25	25.17
T_9 – i_3s_3	15.80	15.22	0.264	0.083	25.14	25.12
C2	15.92	15.43	0.502	0.253	25.17	25.16
SEm(±)	0.133	0.092	0.023	0.025	0.093	0.072
CD(0.05)	NS	NS	0.049	0.036	NS	NS

Table 11.c. Effect of intercropping, spacing and their interaction on total crude protein yield of the intercropping system, t ha^{-1}

Treatments	**Total crude protein yield (t ha^{-1})**
Intercropping(I)	
I_1	2.42
I_2	2.67
I_3	2.37
SEm(±)	0.053
CD(0.05)	0.161
Spacing(S)	
S_1	2.44
S_2	2.51
S_3	2.50
SEm(±)	0.053
CD(0.05)	NS
Intercropping × spacing (I×S)	
i_1 s_1	2.31
i_1 s_2	2.50
i_1 s_3	2.44
i_2 s_1	2.79
i_2 s_2	2.60
i_2 s_3	2.63
i_3 s_1	2.23
i_3 s_2	2.44
i_3 s_3	2.44
SEm(±)	0.131
CD(0.05)	NS

4.5. NUTRIENT UPTAKE

The data with respect to nitrogen uptake, phosphorus uptake and potassium uptake of palisade grass, fodder cowpea and fodder rice bean are presented in Table 12a.and 12b.

4.5.1. Nitrogen uptake

The intercropping had significant effect on nitrogen uptake of palisade grass. Among the treatments, significantly higher nitrogen uptake was recorded by pure crop of palisade grass (377.02 kg ha^{-1}). While the spacing treatments had no significant effect on nitrogen uptake of palisade grass.

The result revealed that treatment combinations had significant effect on nitrogen uptake of palisade grass. Among the treatment combinations, maximum nitrogen uptake was registered by i_1 s_3 (pure crop of palisade grass +60 cm×60 cm) and it was found to be on par with i_1 s_2 (pure crop of palisade grass +60 cm×40 cm) and i_1 s_1 (pure crop of palisade grass +60 cm×30 cm).

In fodder cowpea, nitrogen uptake was significantly improved in the second crop and highest nitrogen uptake was observed with pure crop of fodder cowpea (42.4 kg ha^{-1}).

In the case of fodder rice bean, highest nitrogen uptake was observed with pure crop of fodder rice bean in both harvests.

4.5.2. Phosphorus uptake

Though phosphorus uptake of palisade grass was significantly increased by intercropping, the spacing treatments had no significant effect on P uptake of palisade grass. Among the intercropping treatments, significantly higher phosphorus uptake was recorded by pure crop of palisade grass (47.11 kg ha^{-1}).

The result showed that treatment combinations had significant effect on phosphorus uptake of palisade grass. Among the treatment combinations, maximum phosphorus uptake was recorded by i_1 s_2 (pure crop of palisade grass +60 cm×40 cm) and it was found to be on par with i_1 s_1 (pure crop of palisade grass +60 cm×30 cm), i_1 s_3 (pure crop of palisade grass +60 cm× 60 cm) and i_3 s_3 (intercropping palisade grass with fodder rice bean +60 cm× 60 cm).

Regarding fodder cowpea, treatments had significant effect on phosphorus uptake only in the second crop. Among the treatments, maximum phosphorus uptake was observed with pure crop of fodder cowpea (3.55 kg ha^{-1}).

In the case of fodder rice bean, maximum phosphorus uptake was observed with pure crop of fodder rice bean in both harvests.

4.5.3. Potassium uptake

The intercropping had significant effect on potassium uptake of palisade grass and significantly highest potassium uptake was recorded by pure crop of palisade grass (222.83 kg ha^{-1}). While the spacing treatments had no significant effect on potassium uptake of palisade grass.

However, the interaction effect had no significant influence on potassium uptake of palisade grass.

Regarding fodder cowpea, treatments had significant effect on potassium uptake only in the second crop. Among the treatments, maximum potassium uptake was observed with pure crop of fodder cowpea (10.77 kg ha^{-1}).

In the case of fodder rice bean, maximum potassium uptake was observed with pure crop of fodder rice bean in both harvests.

Table 12.a Effect of intercropping, spacing and their interaction on nitrogen uptake, phosphorus uptake and potassium uptake of palisade grass, kg ha^{-1}

Treatments	Nitrogen uptake(kg ha^{-1})	Phosphorus uptake(kg ha^{-1})	Potassium uptake(kg ha^{-1})
Intercropping(I)			
I_1	377.02	47.11	222.83
I_2	280.80	36.12	169.01
I_3	333.81	39.61	149.15
SEm(±)	5.692	0.781	8.831
CD(0.05)	17.064	2.347	21.638
Spacing(S)			
S_1	331.48	40.22	185.88
S_2	327.08	40.05	175.23
S_3	333.07	42.58	179.88
SEm(±)	5.692	0.781	8.831
CD(0.05)	NS	NS	NS
Intercropping ×spacing (I × S)			
i_1 s_1	371.91	46.56	231.22
i_1 s_2	378.65	48.29	218.74
i_1 s_3	380.51	46.50	218.53
i_2 s_1	305.23	35.72	187.17
i_2 s_2	254.92	36.71	155.82
i_2 s_3	282.27	35.93	164.05
i_3 s_1	317.30	38.38	139.26
i_3 s_2	347.68	35.15	151.13
i_3 s_3	336.45	45.31	157.06
SEm(±)	9.858	1.354	12.494
CD(0.05)	29.552	4.069	NS

Table 12.b Effect of intercropping and spacing on nitrogen uptake, phosphorus uptake and potassium uptake of fodder cowpea and fodder rice bean, kg ha^{-1}

Treatments	Nitrogen uptake ($kg\ ha^{-1}$)		Phosphorus uptake ($kg\ ha^{-1}$)		Potassium uptake ($kg\ ha^{-1}$)	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Fodder cowpea						
T_4- i_2s_1	128.75	13.97	12.19	1.38	38.57	3.97
T_5 - i_2s_2	151.06	12.10	12.41	0.98	39.64	1.66
T_6 - i_2s_3	130.98	16.70	11.91	1.47	40.45	4.47
C_1	144.04	42.40	11.50	3.55	37.37	10.77
SEm(±)	8.633	3.485	0.432	0.318	1.803	0.611
CD(0.05)	NS	12.069	NS	1.100	NS	2.116
Fodder rice bean						
T_7- i_3s_1	31.94	10.12	1.88	0.905	3.87	1.32
T_8 - i_3s_2	34.78	11.44	2.14	1.03	7.56	2.62
T_9 - i_3s_3	42.21	13.81	3.58	1.79	6.78	2.32
C_2	80.36	40.14	6.96	3.48	21.54	10.76
SEm(±)	1.767	1.470	0.155	0.065	0.561	0.395
CD(0.05)	6.123	5.102	0.541	0.244	1.941	1.361

4.6. SOIL ANALYSIS

Table 13 shows the data on organic carbon, available nitrogen, phosphorus and potassium content of soil after the experiment.

4.6.1. Organic carbon

The result revealed that treatments involving intercropping had no significant effect on organic carbon status of the soil. Similarly, spacing treatments also produced no significant variation. Interaction was non-significant with respect to organic carbon content of the soil.

4.6.2. Available nitrogen

The result revealed that treatments involving intercropping had significant effect on available N status of the soil. Intercropping palisade grass with fodder cowpea registered significantly higher nitrogen content in the soil (234.15kg ha^{-1}).

The different spacing treatments had significant effect on available N status of the soil. Among the spacing treatments narrow spacing (60 cm × 30cm) registered maximum available nitrogen content in the soil. Interactions were found to be non significant.

4.6.3. Available phosphorus

The treatments involving intercropping had no significant effect on available P status of the soil. Likewise different spacing treatments produced no significant variation. Interactions were also non-significant.

4.6.4. Available potassium

The result indicated that treatments involving intercropping had no significant effect on available K status of the soil. Among the different spacing treatments, no significant difference was observed. Interactions were non-significant with respect to available K status of the soil.

Table 13. Effect of intercropping, spacing and their interaction on organic carbon content, available nitrogen, phosphorus and potassium of soil

Treatments	Organic carbon (Per cent)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Intercropping(I)				
I_1	0.577	160.97	177.46	267.36
I_2	0.462	234.15	175.12	258.32
I_3	0.454	150.52	170.02	274.35
SEm(±)	0.062	12.006	4.772	5.628
CD(0.05)	NS	36.000	NS	NS
Spacing(S)				
S_1	0.524	213.24	174.43	260.50
S_2	0.388	171.43	175.24	269.69
S_3	0.581	160.97	172.93	269.84
SEm(±)	0.062	12.006	4.772	5.628
CD(0.05)	NS	36.000	NS	NS
Intercropping× spacing(I × S)				
$i_1 s_1$	0.537	188.15	185.53	262.47
$i_1 s_2$	0.463	125.43	172.46	263.89
$i_1 s_3$	0.716	169.34	174.40	275.73
$i_2 s_1$	0.443	275.96	173.12	251.10
$i_2 s_2$	0.303	244.60	184.80	269.15
$i_2 s_3$	0.643	181.88	167.44	254.71
$i_3 s_1$	0.589	175.61	164.64	267.94
$i_3 s_2$	0.393	144.25	168.48	276.04
$i_3 s_3$	0.385	131.71	176.96	279.07
SEm(±)	0.107	20.788	8.273	9.758
CD(0.05)	NS	NS	NS	NS

4.7. ECONOMICS OF INTERCROPPING

The data on economics of the intercropping system is presented in Table 14.

Highest net income of ₹ 170570 ha^{-1} was obtained from T_6 (intercropping palisade grass with fodder cowpea + 60 cm × 60 cm) followed by T_3 (pure crop of palisade grass + 60 cm × 60cm) with a net income of ₹ 165626 ha^{-1}. Higher B: C ratio (1.96) was obtained for T_3, followed by T_6 (1.95). The lowest net income and B: C ratio was registered by pure crop of fodder rice bean.

Table 14. Effect of intercropping and spacing on economics of the intercropping system.

Treatments	Net income (₹) ha^{-1}	B:C ratio
T_1- i_1s_1	145270	1.68
T_2- i_1s_2	130483	1.67
T_3.-i_1s_3	165626	1.96
T_4—i_2s_1	158704	1.72
T_5- i_2s_2	156377	1.78
T_6-i_2s_3	170570	1.95
T_7- i_3s_1	100360	1.45
T_8- i_3s_2	115150	1.57
T_9- i_3s_3	124870	1.69
C_1	78742	1.70
C_2	14009	1.12

DISCUSSION

5. DISCUSSION

The present experiment entitled "Intercropping fodder legumes in palisade grass (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.)" was conducted in the Instructional Farm attached to College of Agriculture, Vellayani to evaluate the production potential of intercropping fodder legumes in palisade grass in terms of yield and quality and also to assess the biological and economic efficiency of the intercropping system. The results of the experiment presented in the previous chapter are discussed here under.

5.1. EFFECT OF INTERCROPPING AND SPACING ON GROWTH PARAMETERS

5.1.1. Palisade grass

The results of the study indicated that intercropping significantly increased plant height of palisade grass in all harvests (Fig.3). The higher plant height in the intercropped plots might be attributed to beneficial effects of mixing grasses and legumes. When legumes are grown along with non-legume crops the N uptake of the companion crop will be enhanced by partitioning the N fixed by legumes to the non-nitrogen fixing crops grown in association with them (Ojo *et al.*, 2013). Similar result was observed by Gulwa *et al.* (2017).

In the first harvest, significantly higher plant height of palisade grass was recorded by intercropping with fodder rice bean and in the fourth harvest, intercropping with rice bean was found to be on par with pure crop of palisade grass and was significantly superior to intercropping with fodder cowpea. This could be attributed to the variation in crop duration of the fodder legumes under study. The duration of fodder rice bean (60 days) was more than that of fodder cowpea (50 days). The increased plant height of palisade grass might be due to the complimentary effect of fodder rice bean. Intercropping systems had more light interception and water and nutrient uptake compared to sole crops, suggesting the

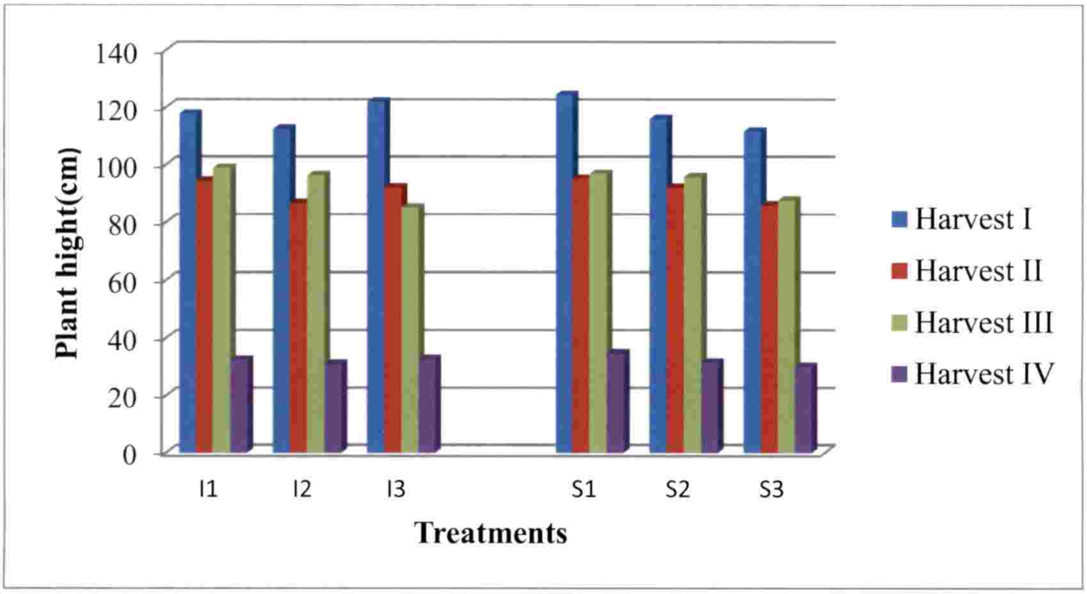

Fig. 3 Effect of intercropping and spacing on plant height of palisade grass

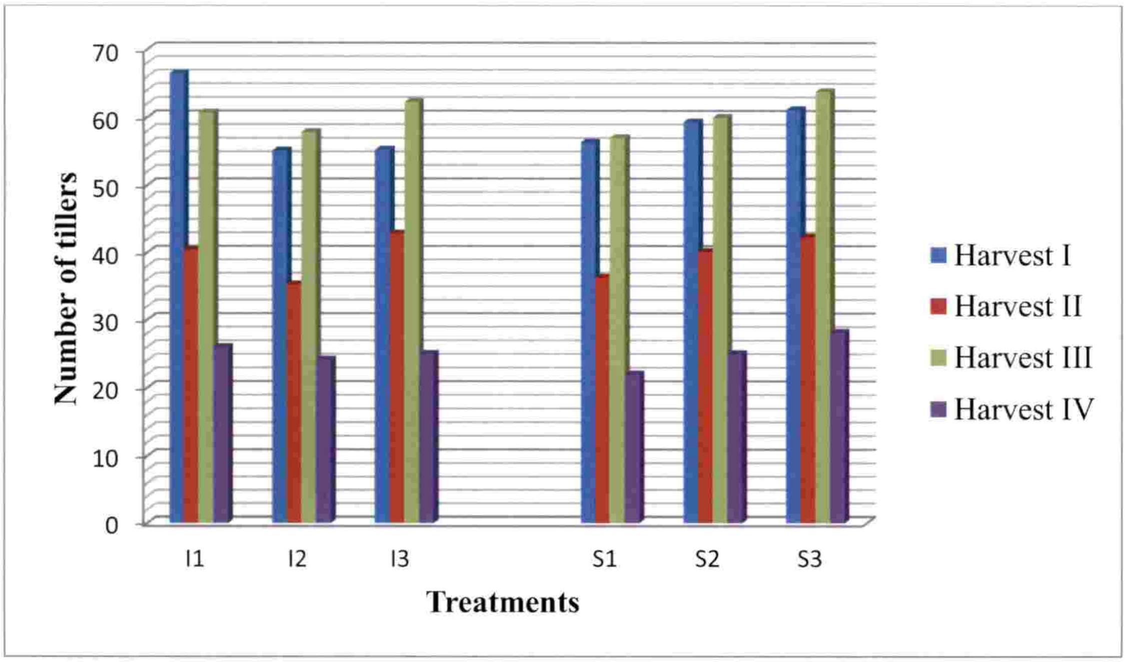

Fig.4 Effect of intercropping and spacing on number of tillers $plant^{-1}$ of palisade grass

complimentary effect of intercropping components in resources consumption (Hamdollah., 2012). The plant height of palisade grass grown as pure crop was found to be on par with intercropping fodder rice bean in second harvest and with intercropping fodder cowpea in third harvest respectively. It is an established fact that when crops are grown in combination, interaction and interference occurs between plant species. The supply of the basic elements (light, nutrients) to one of the crops is reduced by the presence of the other component crop. This reduced supply might have affected the growth of crops (Vandermeer, 1989). Such negative interaction between palisade grass and fodder legumes might have resulted in the increased height of palisade grass in intercropped treatments. This is in conformity with the findings of Gangaiah (2004).

The plant height of palisade grass was significantly influenced by different spacing treatments also. At wider spacing the plant height was found to exhibit a decreasing trend. The narrow spacing treatment recorded highest plant height (60 cm x 30 cm) whereas wider spacing of 60 cm x 60 cm recorded the lowest plant height. Increase in plant population due to closer planting resulted in taller plants. The number of plants per meter square in narrow spacing and wider spacing were six and three respectively. This could be attributed to the fact that closer spacing could enhance the competition for available light. This result is in conformity with the findings of Bagci (2010) in vetch and Sharu (2016) in palisade grass.

Tiller number is an indicator of resource use efficiency in grasses and the number of tillers determines the productivity of the crop. The results of this study revealed that the number of tillers of palisade grass was significantly influenced by intercropping only in first and second harvests (Fig. 4). In the first harvest, highest number of tillers was registered by pure crop of palisade grass. It might be due to decreased competition for resources in pure cropped stands when compared to intercropped plots whereas in the second harvest, highest number of tillers was observed in palisade grass intercropped with fodder rice bean but it was on par with that of pure crop of palisade grass. Apart from fixing atmospheric nitrogen legumes can improve soil tilth by creating deep root channels which ultimately improve soil moisture and aeration. This might have contributed to better nutrient absorption resulting in increased tiller production. Similar result was reported by Anita (2014) in hybrid napier – fodder cowpea mixture and Aladade *et al.* (2013) in guinea grass-stylosanthes mixture. However, tiller production of palisade grass was lowest in fodder cowpea intercropped plots which might have been due to the smothering effect of fodder cowpea.

Significant effect of spacing on number of tillers plant^{-1} was noticed in all harvests except at first harvest. The highest number of tillers was recorded by wider spacing of 60 cm x 60 cm in all harvests. Increased light availability on canopies leads to higher tiller production in grasses. The enhanced tillering occurs through an increased photo assimilate production. Since improved carbon availability leads to enhanced root growth and proliferation, tillering might have increased because of more cytokinins transported from roots (Assuero and Tognetti, 2010). Similar result was observed by Manjunatha *et al.* (2013) in perennial fodder sorghum.

Leaf stem ratio is an important factor determining the selection of diet, quality and forage intake of tropical fodders. The result revealed that the highest leaf: stem ratio was obtained by pure stand of palisade grass in first and fourth harvests. In first harvest, it was on par with intercropping palisade grass with fodder rice bean whereas, in fourth harvest it was on par with intercropping fodder cowpea. In pure cropped plots competition for natural resources are less compared to intercropped plots. Better utilization of resources led to more leafiness in pure cropped plots. Sirait *et al.* (2012) also noticed similar observation in *Brachiaria decumbens.* Intercropping palisade grass with fodder rice bean registered highest leaf: stem ratio of palisade grass in second harvest. The residual effect of decaying leaves and nitrogen fixing ability of legumes might have added more organic matter and nitrogen to the soil which resulted in more vegetative growth in palisade grass.

No significant difference in leaf stem ratio of palisade grass was noticed among the spacing treatments. This could be probably due to the fertility of the soil of the experimental site which resulted in an equal ratio between the leaves and the stem of palisade grass. Similar result was reported by Velayudhum *et al.* (2011) in bajra napier hybrid.

Leaf area index determines light capture and has an important role in fodder productivity. Eventhough the intercropping treatments had no significant influence on LAI, the spacing treatments significantly affected leaf area index significantly in all harvests. In first, third and fourth harvests the highest leaf area index was recorded by narrow spacing (60 cm × 30 cm). In the second harvest, though the leaf area index was highest for 60 x 40 cm spacing treatment, it was on par with 60 cm x 30 cm spacing. The increased plant density in the narrow spacing might have improved the leaf area index. This is in conformity with the reports of Sharu (2016) in palisade grass.

5.1.2. Fodder legumes

The results of the study indicated that intercropping and plant spacing was not significant in the plant height of fodder legumes during two seasons which suggests that both pure crop and intercropping treatments were equally good at all the three spacing. This could be attributed to the better performance of both varieties of legumes in intercropping and pure cropped conditions.

The pure crop of fodder cowpea produced more number of branches only during the second crop season. Ezumah and Ikeorgu (1993) reported reduced cowpea growth and biomass production due to shading by corn in intercropping of corn with cowpea. A similar finding of suppressed cowpea growth in intercropping situation was reported by Ramanakumar and Bhanumurthy (2001). However, there was no significant difference between various treatments involving fodder rice bean.

The pure crop of fodder rice bean produced higher leaf stem ratio and leaf area index in both season which might be due to more number of branches and leaves where plant density was lower. In the case of fodder cowpea, pure crop registered highest leaf stem ratio and leaf area index only in second crop season.

5.2. EFFECT OF INTERCROPPING AND SPACING ON YIELD

5.2.1. Palisade grass

The results of the study revealed that intercropping had significant effect on green fodder yield of palisade grass in first, third and fourth harvests. The green fodder yield of pure crop of palisade grass was significantly higher in all these harvests (Fig. 5). There was a total yield increase of 40 and 24 per cent respectively for pure crop of palisade grass compared to intercropping with fodder cowpea and fodder rice bean. With respect to total green fodder yield, significantly higher yield was observed with sole crop of palisade grass (169.56 t ha^{-1}) followed by intercropping with fodder rice bean and intercropping with fodder cowpea. 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.

Higher green fodder yield of pure crop was contributed by many factors. The main reason was the decreased interspecific competition for available resources which helped in better utilization of space, light, nutrients and water. The improved biometric characters such as plant height, number of tillers and leaf: stem ratio of pure crop of palisade grass have resulted in the increased total green fodder yield. Ahmad *et al.* (2007) in forage sorghum and Bakhashwain (2010) in rhode grass-alfalfa mixtures also observed similar yield improvement in pure crop over intercropping. However, in third and fourth harvest, pure crop of palisade grass and its intercropping with fodder cowpea were found to be on par. Seresinhe *et al.* (1994) opined that inclusion of legume in a pasture mixture, stimulated the growth and increased the N uptake of grass. Similar result was reported by Ayub *et al.* (2004) in sorghum - rice bean mixture.

Significant effect of spacing on green fodder yield of palisade grass was observed only during the first harvest where it was positively related to plant

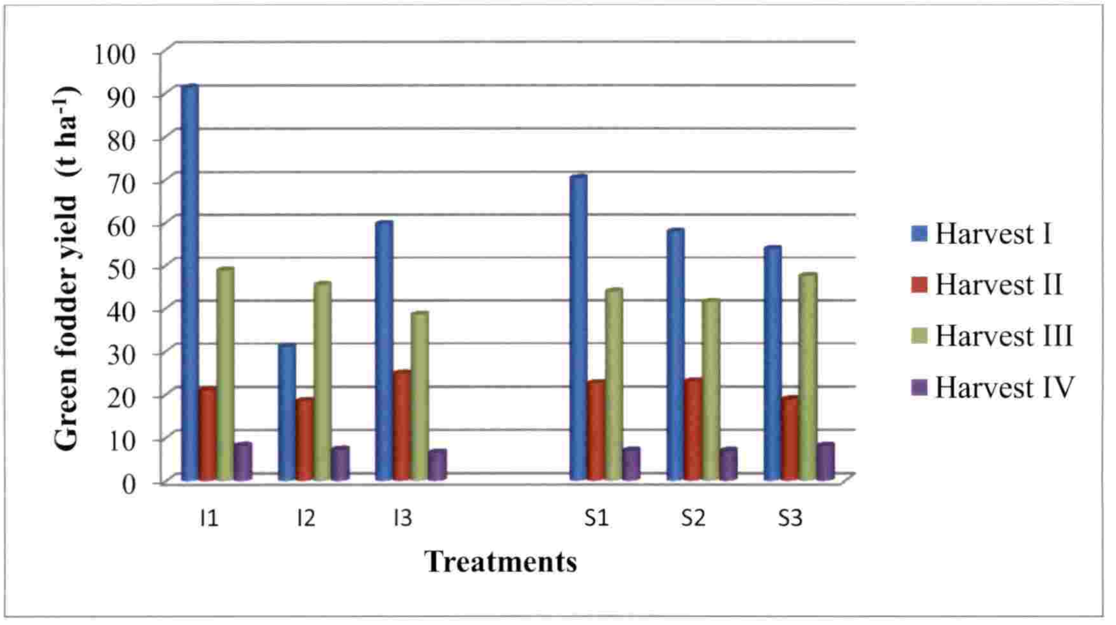

Fig.5 Effect of intercropping and spacing on green fodder yield of palisade grass

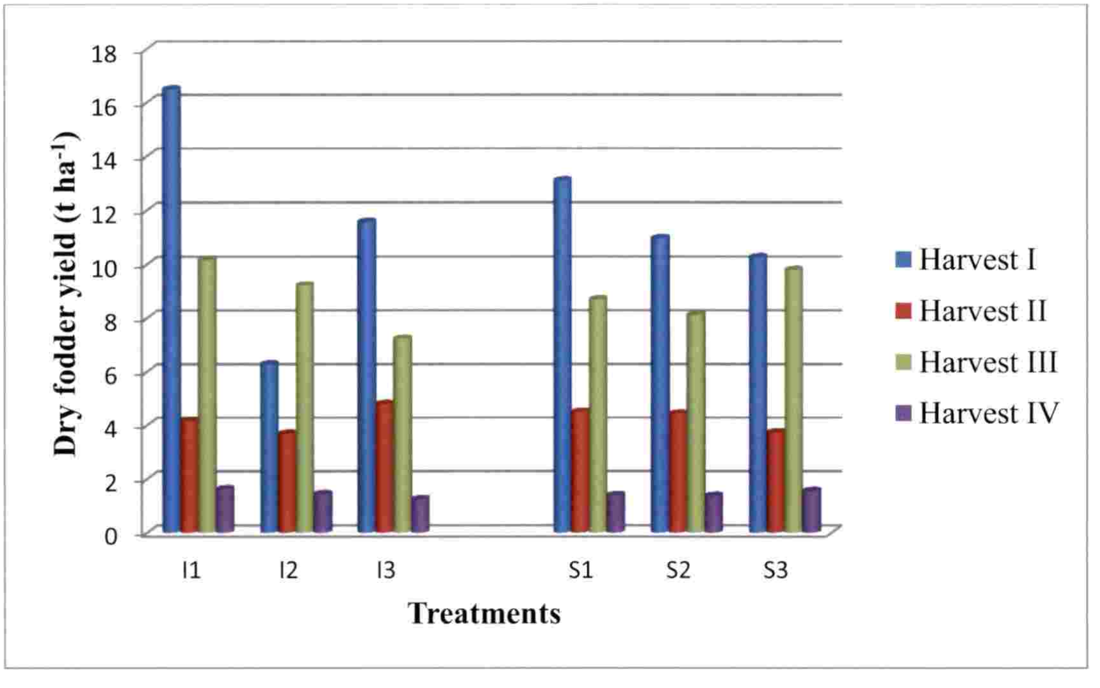

Fig.6 Effect of intercropping and spacing on dry fodder yield of palisade grass

population and the highest yield was recorded by narrow spacing of 60 cm × 30 cm. The results showed 23 and 18 per cent yield improvement by adopting spacing of 60 cm × 30 cm and 60 cm × 40 cm respectively compared to 60 cm × 60 cm. But spacing treatments had no significant effect on total green fodder yield of palisade grass which might be attributed to the low plant density at wider plant spacing and high plant density at narrow plant spacing. Furthurmore, forage yield is a function of growth parameters like plant population, plant height and leaf area index. All these characters were higher for narrow plant spacing which might have contributed to enhanced green fodder yield in closer spacing. This result is in agreement with Wolf *et al.* (1993) in maize. However, Borghi *et al.* (2013) opined that when water and nutrients are not limiting, adopting maize and palisade grass intercropping under both 45 cm and 90 cm row spacing is advantageous for dry matter production without reduction in maize yield. Spacing treatments had no significant effect on total green fodder yield of palisade grass.

The dry fodder yield of palisade grass was significantly increased by intercropping in first, third and fourth harvests. The highest dry fodder yield was registered by pure crop of palisade grass in all harvests (Fig.6). There was a total yield increase of 37.2 and 23.2 per cent respectively for pure crop of palisade grass compared to intercropping with fodder cowpea and fodder rice bean. The total dry fodder yield also had the same trend. Improvement in green fodder yield had a positive influence on dry fodder yield of palisade grass. This result is in conformity with the findings of Baba *et al.* (2011) in grass-legume mixture and Bakhashwain (2010) in rhodes grass- alfalfa mixtures. However in third and fourth harvest, pure crop of palisade grass and its intercropping with fodder cowpea was found to be on par. Dry fodder yield increase in mixture compared with pure stand of palisade grass is probably associated with increased competition of fodder cowpea for the efficient use of environmental resources. Sood and Sharma (1996) observed that maize grown at 60 cm row spacing and intercropped with cowpea, velvet bean and soybean recorded a dry fodder yield increase of 22.03, 28.99, and 12.39 per cent respectively over sole crop of maize grown at 60 cm spacing. Higher dry fodder production with alternate sowing of sorghum with cowpea at full seed rate was reported by Kumbhar *et al.* (1994). Similar result was reported by Ayub *et al.* (2004) in sorghum - rice bean mixture.

Significant influence of spacing treatments on dry fodder yield of palisade grass was observed in the first harvest. In the first harvest, dry fodder yield exhibited an increasing trend with decrease in plant spacing up to 60 cm × 40 cm spacing and was found to be on par with 60 cm × 60 cm. This implies that a further increase in plant spacing will not be beneficial and therefore the 60 cm x 40 cm spacing appears to be the optimum level. According to McKenzie *et al.* (1992) higher plant population speeds up canopy closure and increases interception of PAR needed for carbohydrate production in chick pea. However, spacing treatments had no significant effect on the total dry fodder yield of palisade grass.

5.2.2. Fodder legumes

Among the different treatments involving fodder rice bean, pure crop treatment exhibited enhanced total green fodder yield which might be due to better adaptation of the crop under this situation. But its performance was inferior in the intercropped conditions whereas in the case of fodder cowpea, significant difference was noticed only in second crop season. This could be attributed to the difference in competing ability of the two fodder legumes. The enhanced total dry fodder yield of pure crop of fodder rice bean was due to the improved total green fodder production.

5.3. EFFECT OF INTERCROPPING AND SPACING ON YIELD OF THE SYSTEM

The total green fodder and dry fodder yield of the system (grass + legume) was the highest for sole crop of palisade grass compared to intercropped system because of competition free environment (Fig.7). The total green fodder yield increase was to the tune of 21.25 and 16.14 per cent for pure crop of palisade grass over intercropping with fodder cowpea and fodder rice bean respectively. Kumar (2008) also noticed an increase in fodder yield with sole crop of maize. When grass component was intercropped with short duration legumes, the yield reduction in total green fodder was found to be 21 per cent for fodder cowpea and 16 per cent for fodder rice bean respectively. The cause of such reduction was mainly competition for limiting resource, especially moisture.

5.4. EFFECT OF INTERCROPPING AND SPACING ON BIOLOGICAL EFFICIENCIES

In this study the total LER of the intercropping system was significantly influenced by the treatments. Among the treatments, the highest LER of 1.42 was recorded by T_4 (intercropping palisade grass with fodder cowpea+ 60 cm × 30 cm) and it was found to be on par with T_5 (intercropping palisade grass with fodder cowpea+ 60 cm× 40 cm), T_6 (intercropping palisade grass with fodder cowpea+ 60 cm× 60 cm) and T_8 (intercropping palisade grass with fodder rice bean+ 60 cm× 40 cm). The higher LER of intercropped treatments was mainly due to the better performance of both the crops, especially fodder cowpea and it clearly depicts improved biological efficiency of intercropped treatments. A LER of more than 1.0 reveals an intercropping advantage. In all intercropped treatments, LER value were more than one, indicating the superiority of intercropping palisade grass with fodder legumes over pure crop. The higher interspecific facilitation rather than interspecific competition might have resulted in better land-use efficiency in these treatments (Wahla *et al.*, 2009). Similar result was observed by Ram (2008) in guinea grass and caribbean stylo, Javanmard *et al.* (2009) in maize and soybean and Mohan *et al.* (2013) in maize and rice bean. Among the two fodder legumes, fodder rice bean at all spacing registered lower LER value indicating the superiority of fodder cowpea as the intercrop of palisade grass.

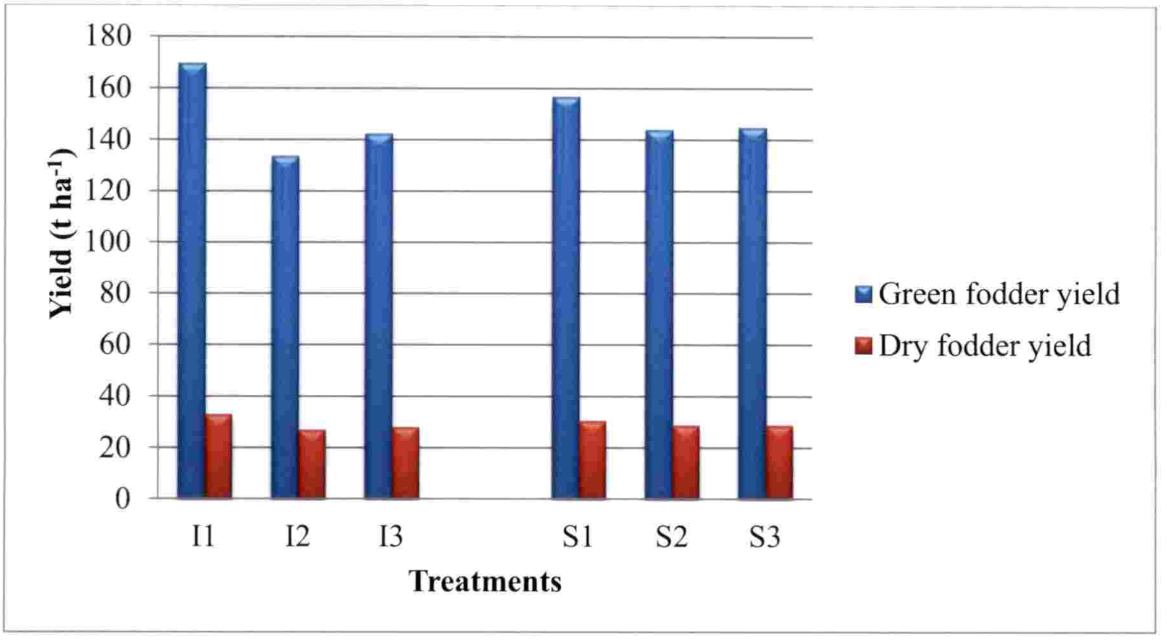

Fig.7 Effect of intercropping and spacing on total green fodder yield and dry fodder yield of the intercropping system (grass+ legume)

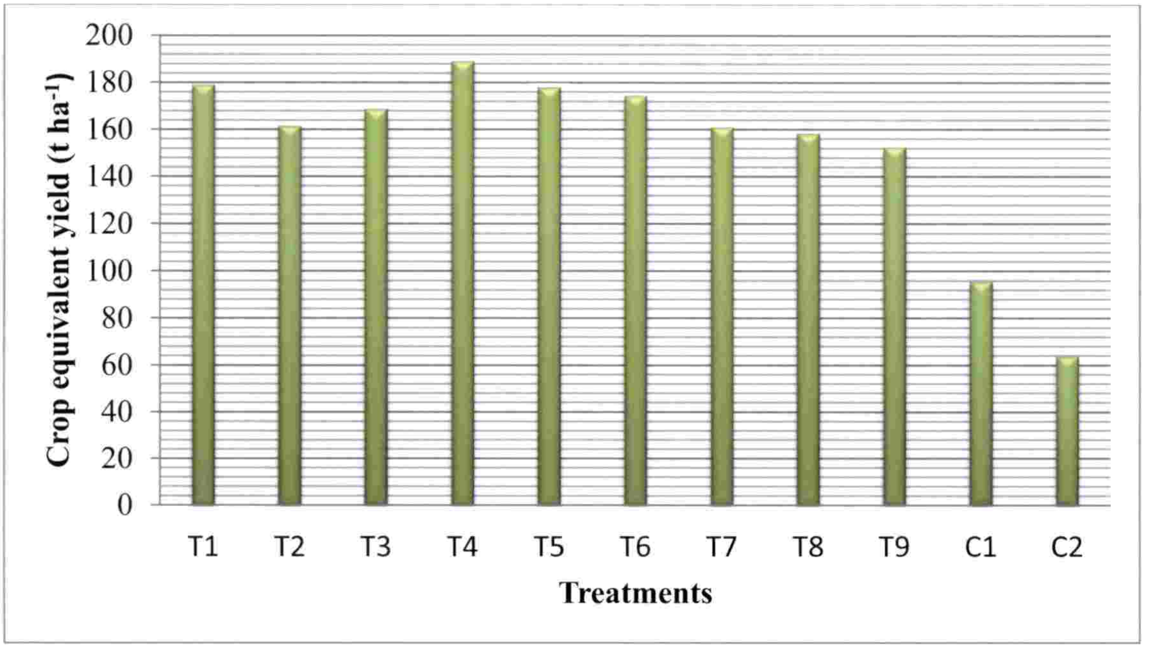

Fig. 8 Effect of intercropping and spacing on crop equivalent yield of intercropping system

Land equivalent coefficient (LEC) was also found to be significantly influenced by the treatments. Among the treatments, T_4 (intercropping palisade grass with fodder cowpea at 60 cm × 30 cm) had the highest LEC and it was found to be on par with T_5 (intercropping palisade grass with fodder cowpea+ 60 cm × 40 cm) and T_6 (intercropping palisade grass with fodder cowpea+ 60 cm × 60 cm). All the treatments recorded a LEC value greater than 0.25 indicating that the system has yield advantage. This clearly reveals the importance of intercropping fodder cowpea with palisade grass. This result is in conformity with the findings of Gayathri (2010) in alley cropping in cassava.

Aggresivity index measures the aggressiveness of one species towards another in a mixture as well as their respective land occupancy. The positive value of aggressivity of fodder cowpea is a reflection of more aggressiveness and high competitive ability, whereas negative value of fodder rice bean indicates its inferior competitive character compared to palisade grass. The performances of various legumes in a mixture vary in their ability to extract available resources. Having higher aggressivity fodder cowpea indicated it as a dominant crop and a superior competitor in the palisade grass- legume combination. Thus in a low input system, palisade grass- fodder cowpea intercropping can be introduced as an alternative to sole crop of palisade grass. More aggressiveness of legumes in grass-legume mixture combination was reported by Baba *et al.* (2011).

For evaluating the system intercrop yields of legumes were converted to yield of palisade grass on the basis of price. The highest crop equivalent yield was recorded by T_4 (intercropping palisade grass with fodder cowpea+ 60 cm × 30 cm) and it was found to be on par with treatments from T_1 to T_7 (Fig.8). Both intercropping systems showed higher equivalent yield in all the spacing treatments. This could be attributed to relatively higher yield of palisade grass under intercropped situation and the additional yield of fodder legumes. Similar findings were reported by Parvender *et al.* (2010). The result again confirm the possibility of including fodder legumes as intercrop in palisade grass based intercropping system which can mainly be attributed to the price difference of grass and legume crops. Similar result was reported by Gayathri (2010).

5.5. EFFECT OF INTERCROPPING AND SPACING ON QUALITY

5.5.1. Palisade grass

The crude protein level of forage is an important factor determining its quality. Significantly higher crude protein content revealed that intercropping palisade grass with both fodder cowpea and fodder rice bean is equally good (Fig. 9). Generally, mixing of legumes in grass fodder is a sustainable way to increase the quality of grass fodder. The nitrogen released from legumes will be used by the grass in mixture. Hence the mixture had higher CP contents than monocultures (Sanderson,2010; Kim and Albrecht.2011). Similar findings were reported by Sirait *et al.* (2012) in *Brachiaria decumbens - Arachis pintoi* mixture, Ayub *et a*l. (2004) in sorghum- rice bean mixture, Alalade *et al.* (2013) in stylosanthes - guniea grass intercropping system and Anita (2014) in hybrid napier-fodder cowpea system.

Among the treatment combinations, maximum crude protein content was registered by i_2s_1 (intercropping palisade grass with fodder cowpea+ 60 cm× 30 cm) and was on par with i_2s_2, i_2s_3 and i_3s_2. Significantly lower content of crude protein was recorded by pure crop of palisade grass which clearly indicates the advantage of legume intercropping.

Among the treatments, significantly higher crude protein yield was registered by pure crop of palisade grass. There was a crude protein yield increase of 28.51 and 14.46 per cent respectively for pure crop of palisade grass compared to intercropping with fodder cowpea and fodder rice bean. It was mainly due to higher dry matter yield produced by pure crop over rest of the treatments. The crude protein yield of grass in the intercropped plots were comparable for both legumes.

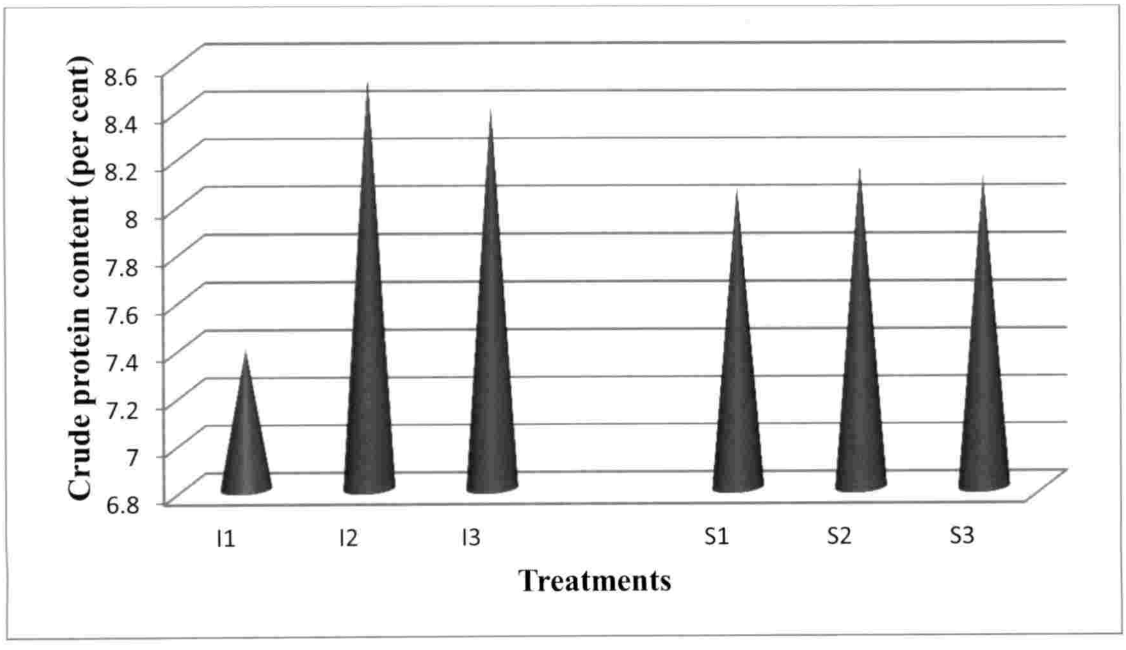

Fig.9 Effect of intercropping and spacing on crude protein content of palisade grass

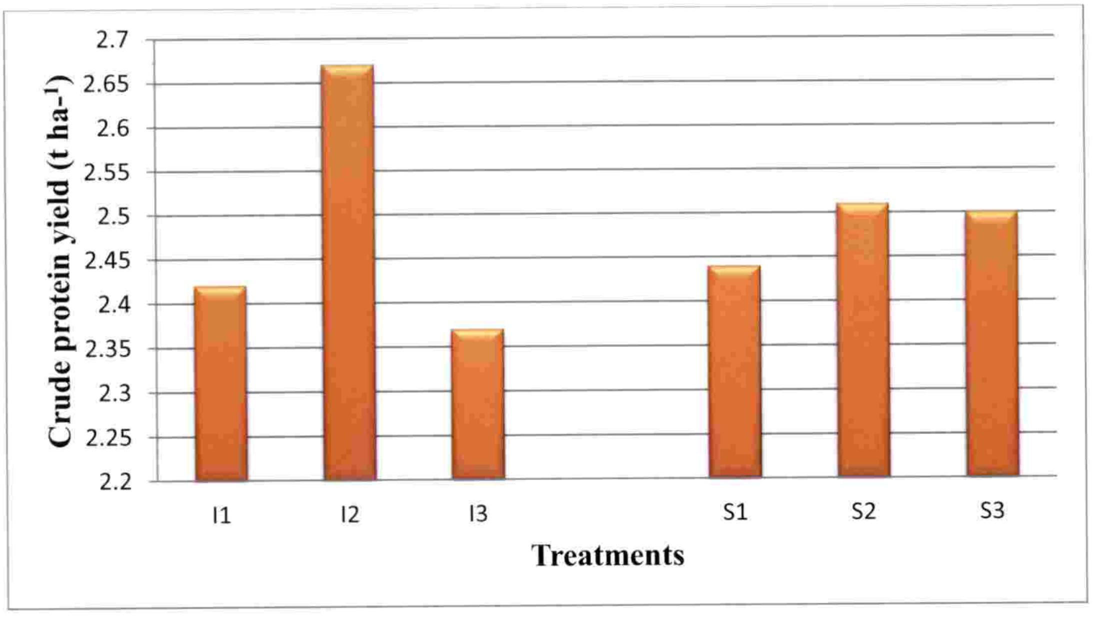

Fig.10 Effect of intercropping and spacing on total crude protein yield of the intercropping system

Among the treatment combinations, maximum crude protein yield was registered by pure crop of palisade grass at 60 cm x 40 cm spacing due to higher dry matter yield.

Intercropping treatments had no significant effect on crude fibre content of the fodder grass. Similar result was reported by Anita (2014) in grass-fodder cowpea intercropping. Similarly spacing treatments also had no significant effect on crude fibre content of the fodder grass. This result is in conformity with the findings of Sharu (2016) in palisade grass

5.5.2. Fodder legumes

The treatments had no significant difference on crude protein content of fodder cowpea and fodder rice bean in both crop seasons. In the fodder rice bean treatments, the highest crude protein yield was with the pure crop in both seasons. But significant difference was noticed only in the second crop season in the case of fodder cowpea. The crude fibre content of fodder cowpea and fodder rice bean was unaffected by different treatments.

5.6. EFFECT OF INTERCROPPING AND SPACING ON QUALITY OF THE SYSTEM

With respect to total crude protein yield of the system, palisade grass along with fodder cowpea was found to be the best intercropping system (Fig.10). There was a crude protein yield increase of 9.36 per cent for intercropping palisade grass with fodder cowpea compared to pure crop of palisade grass. However, no significant influence of spacing was noted on crude protein yield. When palisade grass was intercropped with short duration legumes, like fodder cowpea and fodder rice bean the production of a system depends not only on the efficiency of individual component crop of the system but also on component crops which compliment with each other in time and space.

5.7. EFFECT OF INTERCROPPING AND SPACING ON NUTRIENT UPTAKE

5.7.1. Palisade grass

Highest nitrogen uptake was recorded by pure crop of palisade grass. Palisade grass is a very aggressive, effectively competing grass suitable for tropical conditions. The environmental factors, particularly rainfall was highly favourable throughout the growth stages except final harvest of the crop. The luxurious growth of palisade grass in the absence of intercrops favourably affected the nitrogen uptake.

The N, P and K uptake of palisade grass was significantly influenced by intercropping. Among the intercropping treatments, significantly higher N, P and K uptake were recorded by pure crop of palisade grass (Fig.11). It is clearly evident that the grass exhibited its full potential under sole crop condition where crop competition is minimum. However, the lower N, P and K uptake under intercropped situation may be due to the lower rate of dry matter accumulation. The spacing treatments had no significant effect on N, P and K uptake of palisade grass.

The results showed that the treatment combinations had significant effect on N and P uptake of palisade grass. Among the treatment combinations, the increased uptake of N and P by pure crop of palisade grass at 60 cm x 60 cm and 60 cm x 40 cm spacing respectively may be due to better utilization of resources. Ram (2008) mentioned that the sole crops of guinea grass and *Stylosanthus hamata* obtained significantly higher uptake of nitrogen (47.87 and 58.34 kg ha^{-1}), phosphorus (15.91 and 4.46 kg ha^{-1}) and potash (136.64 and 38.39 kg ha^{-1}) than under intercropping situations.

5.7.2. Fodder legumes

Among fodder rice bean treatments, nutrient uptake was higher for pure crop of rice bean in both seasons whereas with fodder cowpea N, P, K uptake was significantly different only in second crop season. This improved uptake of nutrients in pure crop of legumes was due to the increased nutrient content of the legume crops.

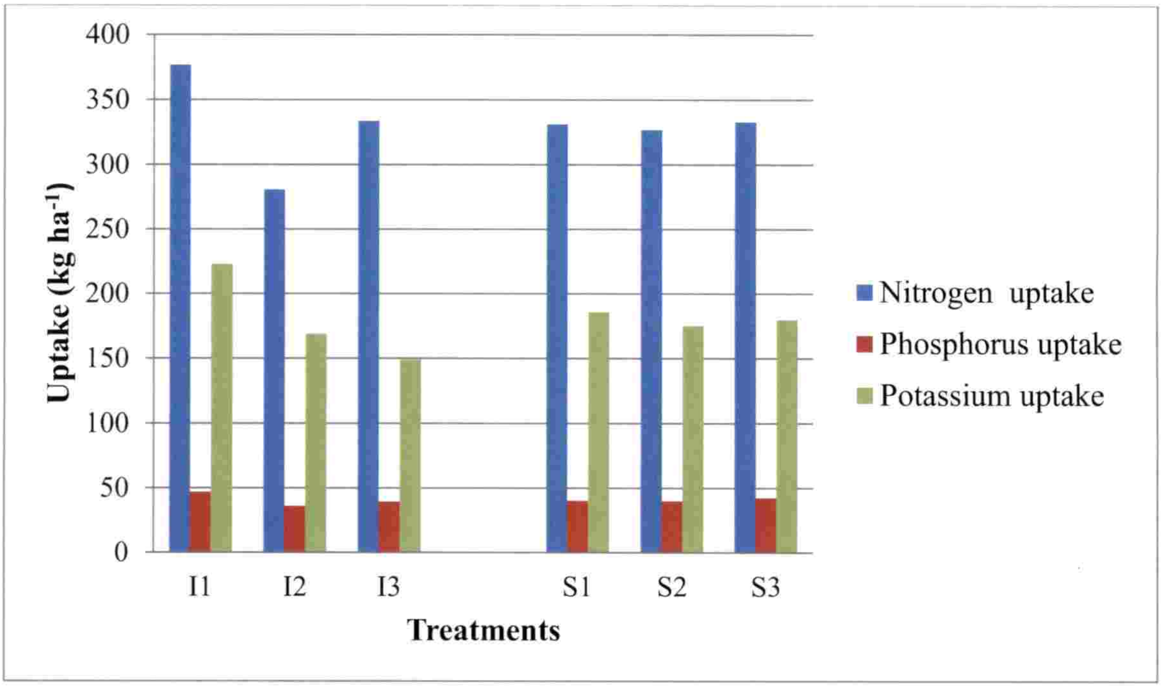

Fig.11 Effect of intercropping and spacing on nitrogen uptake, phosphorus uptake and potassium uptake of palisade grass

5.8. EFFECT OF INTERCROPPING AND SPACING ON NUTRIENT STATUS OF THE SOIL

The results on the chemical analysis of the soil after the experiment showed that treatment had no significant effect on organic carbon content, available phosphorus and available potassium. This could be attributed to the same nutrient regime adopted in all the treatments. Similar result was observed by Anita (2014) in grass-legume intercropping.

However, intercropping and spacing had significant effect on available nitrogen. Intercropping palisade grass with fodder cowpea registered maximum available nitrogen content in the soil. 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). Srinivasaraju *et al.* (1997) reported lower depletion of soil N, P, K in intercropped situations. Anita (2014) also observed similar findings in hybrid napier-fodder cowpea intercropping.

The narrow spacing of 60 cm x 30 cm retained more nitrogen in the soil. In the study, narrow spacing having high plant population produced highest fodder yield indicating the efficiency of nutrient use, particularly nitrogen.

5.9. EFFECT OF INTERCROPPING AND SPACING ON ECONOMICS OF THE INTERCROPPING SYSTEM

The highest net returns was realized by intercropping fodder cowpea in palisade grass at a spacing of 60 cm × 60 cm followed by pure crop of palisade grass with same spacing (Fig.12) whereas, B: C ratio obtained for both treatments were similar. Fodder cowpea is a high priced fodder than palisade grass which resulted in the increased income from intercropping although, total fodder yield was higher for pure crop of palisade grass. Similar results were observed by Ram (2008) in guinea

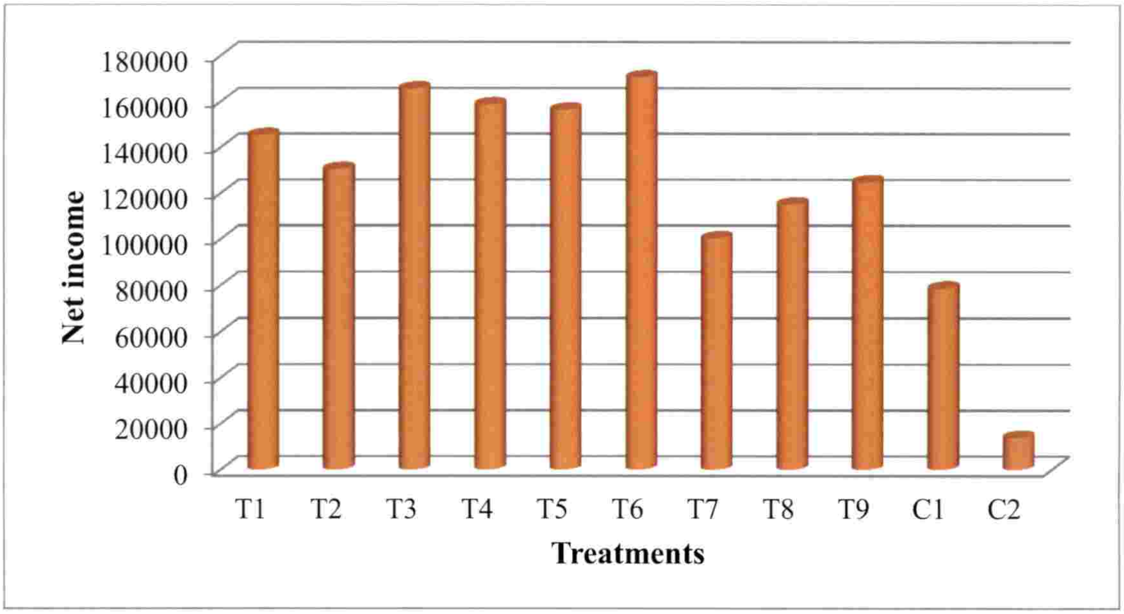

Fig. 12 Effect of intercropping and spacing on net income (₹) of the intercropping system

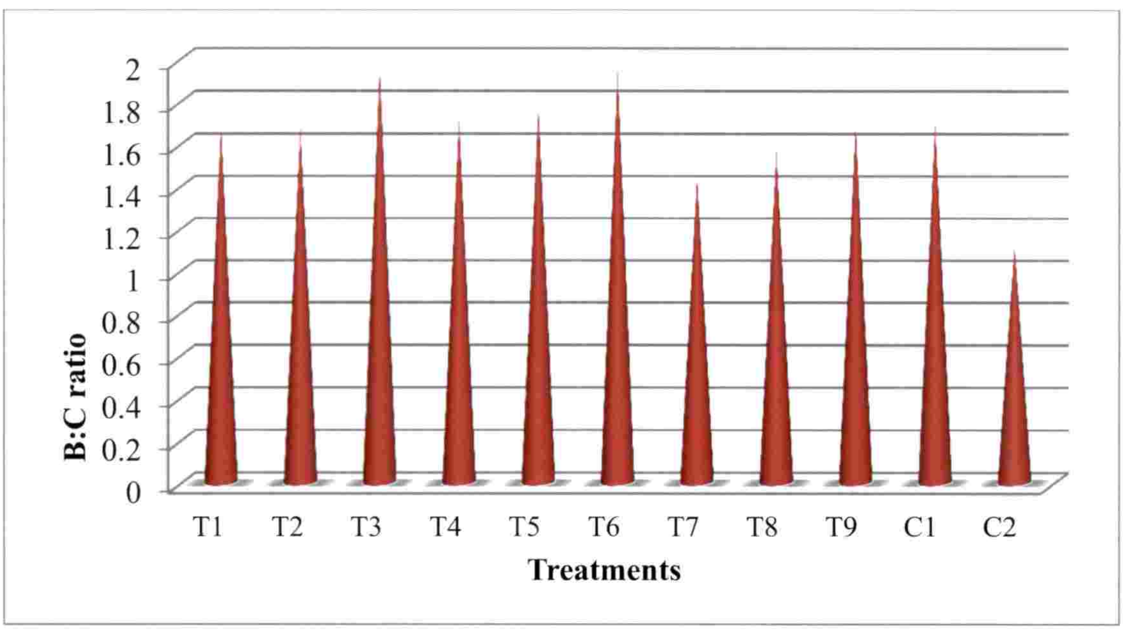

Fig.13 Effect of intercropping and spacing on BC ratio of the intercropping system

grass and caribbean stylo and Verma *et al.* (2011) in cowpea and guinea grass. In all intercropped treatments, B: C ratio was more than 1.00 indicating that intercropping fodder legumes in palisade grass was economical (Fig.13). The lowest net returns and B: C ratio was obtained by sole crop of fodder rice bean because of the lower fodder yield due to the lesser adaptability of the crop in our climatic condition.

The results of the present study, indicated that integration of fodder cowpea in palisade grass based intercropping system had a favourable effect on the overall fodder production. Even though, total green fodder yield was the highest for pure crop of palisade grass, economic and quality wise performance was superior for palisade grass intercropped with fodder cowpea. Highest crude protein content, total crude protein yield, net returns and benefit cost ratio of palisade grass + fodder cowpea treatment, confirms the superiority of fodder cowpea in palisade grass. Among the two fodder legumes, fodder cowpea was very promising and holds good with respect to yield and quality. Moreover, competing ability and yield advantage of fodder cowpea was more supportive with palisade grass than fodder rice bean. Though the crude protein content of both legumes were equally good, the green fodder yield of fodder rice bean was very poor. Unfortunately, the adaptability problem of fodder rice bean was very crucial throughout the cropping period and it reflected in the yield to a great extend. The total yield reduction of rice bean compared to fodder cowpea at 60 cm x 30 cm, 60 cm x 40 cm and 60 cm x 60 cm was 68 per cent, 70 per cent and 59 per cent respectively. In addition to the mixing of crops, plant spacing was another important factor for higher yield realization. Though total green fodder yield was higher for 60 x 30 cm spacing treatment, wider spacing treatment (60 cm x 60 cm) holds good with respect to economic aspect. Thus, in the present study inclusion of fodder cowpea in palisade grass at a spacing of 60 x 60 cm proved to be the best combination in terms of crop equivalent yield, quality and economics.

SUMMARY

6. SUMMARY

The field experiment entitled "Intercropping fodder legumes in palisade grass (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.)" was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during June 2017 to March 2018 to evaluate the production potential of intercropping fodder legumes in palisade grass in terms of yield and quality and also to assess the biological and economic efficiency of the intercropping system.

The experiment was laid out in randomized block design (factorial) with three replications. The treatments consisted of three levels of intercropping (I_1-no intercropping, I_2-intercropping with fodder cowpea and I_3 -intercropping with fodder rice bean), three spacing (S_1- 60 cm x 30 cm, S_2- 60 cm x 40 cm and S_3- 60 cm x 60 cm) and two controls (C_1- pure crop of fodder cowpea and C_2 - pure crop of fodder rice bean). FYM @ 10 t ha^{-1} was uniformly applied to all the plots at land preparation. In the treatments involving palisade grass + fodder legumes and palisade grass alone, N, P and K @ 300:75:75 kg ha^{-1} (1/2 N, 1/2 P and 1/2 K as basal dose and 1/2 N, 1/2 P and 1/2 K after the second harvest of palisade grass) was applied. For pure crop of fodder legumes (fodder cowpea and fodder rice bean) N, P and K @ 25: 60:30 kg ha^{-1} was applied and the entire dose was given as basal. The fodder legumes were sown twice (along with the planting of palisade grass and after the second harvest of palisade grass) in between two rows of palisade grass at a spacing of 30 cm× 15 cm.

The salient findings of the study are summarized in this chapter.

The highest plant height was recorded by intercropping palisade grass with fodder rice bean in first and fourth harvest (121.81 and 32.75cm) and it was found to be on par with pure crop of palisade grass. But in the second and third harvest, highest plant height was observed with pure crop of palisade grass (94.33 and 98.75 cm) and it was found to be on par with intercropping with fodder rice bean in the second harvest (91.91 cm) and intercropping with fodder cowpea in the third harvest (96.19 cm).

Among the spacing treatments, highest plant height was recorded by narrow spacing (60 cm x 30 cm) in all harvests and it was found to be on par with 60 x 40 cm in second and third harvest. In all the harvests wider spacing (60 x 60 cm) recorded lowest plant height of palisade grass.

Intercropping and spacing was not significant on the plant height of fodder legumes during two seasons.

Significantly higher number of tillers was registered by pure crop of palisade grass (66.4) in the first harvest. But in the second harvest, highest number of tillers was observed in intercropping palisade grass with rice bean (42.88) and it was found to be on par with sole crop of palisade grass (40.44). Among the spacing treatments, highest number of tillers was recorded by wider spacing of 60 cm x 60 cm and it was found to be on par with S_2 (60cm × 40 cm).

Eventhough no significant effect was observed on number of branches in first crop of fodder cowpea, pure crop of fodder cowpea recorded highest number of branches (3.00) in the second crop.

The highest leaf: stem ratio was obtained by pure stand of palisade grass in first and fourth harvests (1.30 and 2.08) and it was found to be on par with intercropping palisade grass with fodder rice bean in first harvest and intercropping palisade grass with fodder cowpea in the fourth harvest. However, in the second harvest significantly higher leaf: stem ratio of 3.21 was observed with intercropping palisade grass with fodder rice bean.

Highest leaf area index was registered by narrow spacing, S_1 (60 cm × 30 cm) in first, third and fourth harvest. But in the second harvest, highest leaf area index was observed with S_2 (60 cm × 40 cm) and it was found to be on par with S_1 (60 cm × 30 cm).

The pure crop of fodder rice bean produced higher leaf stem ratio and leaf area index in both season. In the case of fodder cowpea, pure crop registered highest leaf stem ratio and leaf area index only in second crop season

The total green fodder yield (169.56 t ha^{-1}) and dry fodder yield (32.95 t ha^{-1}) was significantly higher with sole crop of palisade grass followed by intercropping with fodder rice bean and intercropping with fodder cowpea.

The total green fodder yield and dry fodder yield of the system was also significantly higher in sole crop of palisade grass.

Among the different treatments involving fodder rice bean, pure crop treatment exhibited enhanced total green fodder and dry fodder yield whereas in the case of fodder cowpea, significant difference was noticed only in second crop season.

The highest LER (1.42) was registered by T_4 (intercropping palisade grass with fodder cowpea+ 60 cm × 30 cm) and it was found to be on par with T_6 (intercropping palisade grass with fodder cowpea+ 60 cm× 60 cm) and T_5 (intercropping palisade grass with fodder cowpea+ 60 cm× 40 cm).The same trend was seen in LEC of the system.

Among the treatments, T_8 (intercropping palisade grass with fodder rice bean+ 60 cm × 40 cm) registered highest aggressivity index of 1.43 and was on par with T_7.

The highest crop equivalent yield of 188.93 t ha^{-1} was recorded by T_4 (intercropping palisade grass with fodder cowpea+ 60 cm × 30 cm) and it was found to be on par with all the treatments from T_1 to T_7.

Intercropping palisade grass with fodder cowpea (I_2) recorded highest crude protein content of 8.53 per cent and it was found to be on par with intercropping palisade grass with fodder rice bean (I_3). Among the treatment combinations, maximum crude protein content was registered by i_2 s_1 (intercropping palisade grass with fodder cowpea+ 60 cm×30 cm) and it was found to be on par with i_3 s_2 (intercropping palisade grass with fodder rice bean+ 60 cm× 40 cm), i_2 s_2 (intercropping palisade grass with fodder cowpea + 60 cm× 40 cm) and i_2 s_3 (intercropping palisade grass with fodder cowpea+ 60 cm× 60 cm).

The significantly higher crude protein yield was registered by pure crop of palisade grass (2.42 t ha^{-1}). Among the treatment combinations, maximum crude protein yield was registered by i_1 s_2 (pure crop of palisade grass + 60 cm×40 cm) and it was found to be on par with i_1 s_3 (pure crop of palisade grass + 60 cm× 60 cm). With respect to fodder cowpea, in the second crop highest crude protein yield was recorded by pure crop of fodder cowpea (0.263 t ha^{-1}). In the case of fodder rice bean, maximum crude protein yield was observed with pure crop of fodder rice bean in both harvests.

The total crude protein yield of the system was highest for intercropping palisade grass with fodder cowpea (2.67 t ha^{-1}).

Significantly higher N, P and K uptake of palisade grass were recorded by pure crop of palisade grass. Among the treatment combinations, the increased uptake of N and P were recorded by pure crop of palisade grass at 60 x 60 cm and 60 x 40 cm respectively.

Among fodder rice bean treatments, nutrient uptake was higher for pure crop of rice bean in both seasons whereas with fodder cowpea treatments N, P, K uptake was significant only in second crop season.

Intercropping palisade grass with fodder cowpea registered significantly higher nitrogen content in the soil (234.15kg ha^{-1}). Among the spacing treatments narrow spacing (60 cm× 30cm) registered maximum available nitrogen content in the soil.

Highest net income of ₹ 170570 was registered by T_6 (intercropping palisade grass with fodder cowpea + 60 cm × 60 cm) followed by T_3 (pure crop of palisade grass + 60 cm × 60cm). Higher B: C ratio of 1.96 was obtained for T_3, followed by T_6 with a B: C ratio of 1.95.

Future line of work

- The study may be conducted with single row of fodder legumes in between two rows of palisade grass.
- The possibility of yield improvement by intercropping palisade grass with other leguminous fodder crops needs to be experimented.
- The standardization of grass - legume mixture for quality silage production needs to be explored.

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INTERCROPPING FODDER LEGUMES IN PALISADE GRASS (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.)

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Abstract of the thesis

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ABSTRACT

The study entitled "Intercropping fodder legumes in palisade grass (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.)" was conducted during June 2017 to March 2018 in the Instructional Farm, College of Agriculture, Vellayani. The objectives were to evaluate the production potential of intercropping fodder legumes in palisade grass in terms of yield and quality and also to assess the biological and economic efficiency of the intercropping system.

The experiment was laid out in randomized block design with three replications. The treatments consisted of three levels of intercropping (I_1-no intercropping, I_2-intercropping with fodder cowpea and I_3 -intercropping with fodder rice bean), three spacing (S_1- 60 cm x 30 cm, S_2- 60 cm x 40 cm and S_3- 60 cm x 60 cm) and two controls (C_1- pure crop of fodder cowpea and C_2 - pure crop of fodder rice bean). Palisade grass variety Mulato, fodder cowpea variety CO-9 and fodder rice bean variety Bidhan-2 were used for the study. FYM @ 10 t ha^{-1} was uniformly applied to all the plots at land preparation. In the treatments involving palisade grass + fodder legumes and palisade grass alone, N, P and K @ 300:75:75 kg ha^{-1} (1/2 N, 1/2 P and 1/2 K as basal dose and 1/2 N, 1/2 P and 1/2 K after the second harvest of palisade grass) was applied. For pure crop of fodder legumes (fodder cowpea and fodder rice bean) N, P and K @ 25: 60:30 kg ha^{-1} was applied and the entire dose was given as basal. The fodder legumes were sown twice (along with the planting of palisade grass and after the second harvest of palisade grass) in between two rows of palisade grass at a spacing of 30 cm× 15 cm.

In the experiment, pure crop of palisade grass (I_1) registered significantly higher green fodder yield, dry fodder yield, crude protein yield, uptake of nutrients and B: C ratio. Palisade grass + fodder cowpea (I_2) recorded the highest green fodder yield of legume, dry fodder yield of legume, land equivalent ratio, land equivalent coefficient, aggressivity, crop equivalent yield, crude protein content of grass, crude

protein yield of grass-legume mixture, available soil nitrogen and net returns. Among the two fodder legumes, fodder cowpea performed better than fodder rice bean with respect to yield, quality and economics.

Among the spacing treatments, significantly higher plant height of palisade grass was registered by narrow spacing of 60 cm x 30 cm in first and fourth harvest and it was on par with 60 cm x 40 cm spacing in second and third harvest. The highest numbers of tillers were produced by 60 cm x 60 cm spacing whereas LAI was the highest for 60 cm x 30 cm spacing. The spacing, 60 cm x 30 cm recorded the highest green fodder yield of palisade grass only in the first harvest. The total green fodder yield, total dry fodder yield, crude protein content, crude protein yield and uptake of nutrients of palisade grass were not significantly influenced by spacing treatments. However, net income and B:C ratio were the highest under the widest spacing (60 cm x 60 cm).

Based on these results, it can be concluded that intercropping two rows of fodder cowpea in between two rows of palisade grass planted at a spacing of 60 x 60 cm is the best combination in terms of crop equivalent yield, quality and economics.

സംഗ്രഹം

തീറ്റപുല്ല് ഇനത്തിൽപ്പെട്ട പാലിസൈഡ് പുല്ലിൽ ഇടവിളയായി തീറ്റപയറുകൃഷി എന്ന വിഷയത്തെ ആസ്പദമാക്കി ഒരു പഠനം 2016 - 2017 കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിലെ അഗ്രോണമി വിഭാഗത്തിൽ വെച്ചു നടത്തുകയുണ്ടായി. വിളവിലും ഗുണമേന്മയിലും ജൈവികക്ഷമതയിലും വിറ്റുവരവിലും ഇടവിളക്ക്യഷിയുടെ സ്വാധീനം വിലയിരുത്തുക ആയിരുന്നു പഠനത്തിന്റെ പ്രധാനലക്ഷ്യം.

റാൻഡമൈസ്ഡ്ബ്ലോക്ക് ഡിസൈൻ എന്ന രീതി അവലംബിച്ച് നടത്തിയ പരീക്ഷണത്തിൽ ഇടവിളക്ക്യഷിയുടെ മൂന്ന് തലങ്ങളും (ഇടവിളയില്ലാതെ,വൻപയറുൾപ്പെട്ട ഇടവിളകൃഷി,അരിപ്പയറുൾപ്പെട്ട ഇടവിള കൃഷി) ചെടികൾ തമ്മിലുള്ള അകലത്തിന്റെ മൂന്ന് തോതും (60 x 30 സെമി, 60 × 40 സെമി, 60 x 60 സെമി) പഠന വിധേയമാക്കി.

പഠനത്തിന്റെ പ്രധാന കണ്ടെത്തലുകൾ ചുവടെ ചേർക്കുന്നു. വൻപയറുവെച്ചുള്ള ഇടവിളകൃഷി ഗുണമേന്മയിലും ജൈവികക്ഷമതയിലും അറ്റാധായത്തിലും മികച്ചതായി കണ്ടു. തനിവിളയായി വളർത്തിയ പുല്ല് വിളവിലും പോഷണ മൂലകങ്ങളുടെ ആഗിരണത്തിലും വിറ്റുവരവിലും മുന്നിട്ടുനിൽക്കുന്നതായി കണ്ടു. 60 x 60 സെമി എന്ന ചെടി അകലം മികച്ച അറ്റാധായവും വിറ്റുവരവും രേഖപെടുത്തി. പരീക്ഷണഫലങ്ങളുടെ അടിസ്ഥാനത്തിൽ 60 x 60 സെമി അകലത്തിൽ നട്ട പാലിസൈഡ് തീറ്റ പുല്ലിനിടക്കു രണ്ടുവരി വൻപയറു നടുന്നതു ഗുണമേന്മയിലും ജൈവികക്ഷമതയിലും വിറ്റുവരവിലും മികച്ചതായി കണ്ടെത്തി.

APPENDIX

APPENDIX I

Weather parameters during the cropping period – June 6th 2017 to March 18th 2018.

Month	Temperature (^{o}C)		Relative Humidity (%)		Bright sunshine hours	Rainfall (mm)	Evaporation (mm)
	Max.	Min.	Max.	Min.			
June, 2017	31.4	24.5	92.29	80.5	7.9	278.7	3.9
July, 2017	31.6	24.7	90.61	77	8.5	48.7	4.0
August, 2017	30.5	24.6	92.16	78.32	7.7	93	3.7
September, 2017	31.5	24.5	92.50	78.93	7.7	297.8	3.6
October 2017	31.1	24.9	94.5	84.9	7.2	221.6	3.6
November, 2017	30.8	24.2	94.90	82.50	5.2	193.2	3
December, 2017	31.8	23.4	94.66	77.38	7.2	173.7	3.3
Januvary, 2018	31.70	21.79	93.54	73.73	8.51	0	3.98
Februvary, 2018	32.47	23.62	92.89	75.42	9.13	0	4.07
March, 2018	33.23	24.28	92.94	74.72	8.08	5.9	4.12

APPENDIX II

Cost of cultivation

Sl. No	Particulars	Units(ha^{-1})	Unit cost(₹)	Total cost (₹ ha^{-1})
I	Cost of inputs			
a)	Planting material			
i)	Slips			
	Palisade grass at 60 × 30 cm spacing	55000 No's	0.75 $slip^{-1}$	41,250
	Palisade grass at 60 × 40 cm spacing	41666 No's	0.75 $slip^{-1}$	31,250
	Palisade grass at 60 × 60 cm spacing	27500 No's	0.75 $slip^{-1}$	20,625
ii)	Fodder cowpea seed	15kg	100 kg^{-1}	1,500
iii)	Fodder rice bean seed	15kg	600 kg^{-1}	9,000
b)	Manures and Fertilizers			
i)	FYM	10 t	850 t^{-1}	8,500
ii)	Lime	250 kg	16 kg^{-1}	4,000
iii)	Urea	652 kg	9 kg^{-1}	5,868
iv)	Rajphos	416 kg	10 kg^{-1}	4,160
v)	MOP	125 kg	18 kg-^{1}	2,250
II	Cost of labour	200 No's	741 day^{-1}	1,48,200
III	Cost of outputs			
a)	Palisade grass	₹ 2 kg^{-1}		
b)	Fodder legumes	₹ 5 kg^{-1}		