Alley cropping in cassava (*Manihot esculenta* Crantz.) for food –fodder security

GAYATHRI, P.

Thesis submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

`

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2010

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695522

DECLARATION

I hereby declare that this thesis entitled '**Alley cropping in cassava (*Manihot esculenta* Crantz.) for food - fodder security**' 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 any degree, diploma, associateship fellowship or other similar title of any other university or society.

Vellayani,
08-09-2010

Gayathri. P
(2008 - 11- 109)

CERTIFICATE

Certified that this thesis entitled '**Alley cropping in cassava (*Manihot esculenta* Crantz.) for food - fodder security'** is a record of research work done independently by Miss. Gayathri.P. under my guidance and supervision and that it has not previously formed the basis of the award of any degree, fellowship or associateship to her.

Vellayani,
08-09-2010

Dr. S. Lakshmi
(Chairman, Advisory Committee)
Professor,
Department of Agronomy,
College of Agriculture,Vellayani.

Approved by

Chairperson:

Dr. S. LAKSHMI
Professor,
Department of Agronomy,
College of Agriculture, Vellayani,
Thiruvananthapuram,695522.

Members :

Dr. M. ABDUL SALAM
Professor and Head,
Department of Agronomy,
College of Agriculture, Vellayani.

Dr. R. PUSHPAKUMARI
Professor,
Department of Agronomy,
College of Agriculture, Vellayani.

Dr. K.S. MEENAKUMARI
Professor,
Department of Agricultural Microbiology,
College of Agriculture, Vellayani.

Acknowledgement

I feel great pleasure and privilege to express my deep felt gratitude, indebtedness and sincere thanks to Dr. S. Lakshmi, Professor, Agronomy, College of Agriculture, Vellayani and Chairperson of my advisory committee for her expert guidance, constant encouragement, patience, whole hearted interest and above all the kind of understanding throughout the period of investigation and preparation of thesis. I was fortunate enough to have worked under her guidance.

I express my sincere thanks to Dr. M. Abdul Salam, Professor and Head, Department of Agronomy for his interest, expert advice and creative suggestions in preparation of the thesis.

I have great pleasure to express my heartfelt thanks to Dr.R.Pushpakumari, Professor, Agronomy for her valuable advice, constant support, everwilling help at all stages of work.

I am grateful to Dr. K.S. Meenakumari, Professor, Agricultural Microbiology, for her valuable suggestions and timely help rendered at various stages of the work.

I wish to acknowledge with gratitude the advice and immense help rendered by Dr.C.Nandakumar, Professor, Entomology for adopting timely and effective plant protection measures. I record my thanks to Dr.Roy Stephen and Dr.Manju for giving the freedom to use the lab for conducting the chemical analysis required for the work.

I take this opportunity to pay my sincere thanks to Sri C.E. Ajithkumar Department of Agrl. Extension for his help in timely statistical analysis of the thesis data.

I sincerely express my obligations to all teachers of Department of Agronomy for their whole hearted support, valuable advice and good will bestowed on me. I also express my gratitude to every non teaching staff members of department of Agronomy for their sincere cooperation and assistance during the course of study.

I should specially mention the constant support, encouragement, unrelenting and indispensible help rendered by my friends Jinsy, Gayathri Karthikeyan, Abhijith, Amala, Praveena, Lekshmi and Golda throughout the period of study. I also thank my seniors Rani chechi and Srikanth chetan and my juniors for their support and cooperation.

I sincerely thank the facilities rendered by the library of college of Agriculture, Vellayani.

I am grateful to KAU for granting me the Junior Research Fellowship.

Words fail to express my deep sense of gratitude and indebtedness to my parents and my sister for their unconditional love, encouragement, moral support and blessings.

Finally I thank all those who extended help and support to me during the course of my work

Above all I gratefully bow before the god almighty for the blessings showered upon me in completing the thesis work successfully.

Gayathri. P

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

LIST OF ABBREVIATIONS

@	-	At the rate of
°C	-	Degree Celsius
%	-	Percent
AMF	-	Arbuscular Mycorrhizal Fungi
CD	-	Critical difference
CEY	-	Crop equivalent yield
cm	-	Centimeter
et al.	-	And others
DAP	-	Days after planting
DAS	-	Days after sowing
Fig	-	Figure
FYM	-	Farmyard manure
ie	-	That is
K	-	Potassium
kg ha^{-1}	-	Kilogram per hectare
LAI	-	Leaf Area Index
LEC	-	Land equivalent coefficient
LER	-	Land equivalent ratio
m	-	Meter
MAP	-	Month after planting
N	-	Nitrogen
NS	-	Non significant
P	-	Phosphorus
Plant $^{-1}$	-	Per plant
Rs	-	Rupees
SE	-	Standard error
t ha^{-1}	-	Tonnes per hectare
VAM	-	Vesicular Arbuscular Mycorrhizae

1. INTRODUCTION

To meet the increasing demand for food grain production, agricultural productivity of the land has to be increased which must be sustainable while maintaining the non renewable resource base with minimum environmental degradation. An appropriate technology that will ensure sustained crop production without adversely affecting the natural resource base is therefore required. The practice of growing two or more crops on the same piece of land is generally done to increase production, to diversify products, to minimize risk and to complement one another, by using the resources in different ways.

Due to increasing pressure on land for food grain and cash crop production, good quality arable land for feed and fodder production is decreasing. Thus the fodder production system cannot depend excessively on land and labour required for crop production and should require only low investment. This implies the need for crop – livestock integration to optimise overall productivity and to make agriculture more sustainable. Alley cropping offers a means of linking arable crop production with live stock, which involves growing agronomic, horticultural or forage crops in the alleys of perennial shrubs or trees.

Alley cropping is a method to diversify and intensify production. An alley cropping system is capable of stabilizing productivity and utilizing the resources more efficiently. Alley farming allows longer cropping period with increased land use intensity (Kang et al. 1989). More research is needed on the suitability of alley farming for a wide range of crops across different ecological zones along with the studies of management system that allows the integration of crop and livestock production which supplies high quality low cost supplement to animals to normal diet of animals and small farmer holdings (Kang et al., 1990).

Cassava is the most important tuber crop of Kerala which forms an integral part of most of the cropping systems in the state. The cropping environment is mainly rainfed marginal uplands due to its capacity for high carbohydrate production per unit area. Since the development of cassava in initial stages is very slow a sole crop of cassava does not efficiently use the available land, light and water and nutrient resources, during its early developmental stages. Therefore a short duration crop can be integrated in the system to make more efficient use of land and other growth factors.

In paired row system of planting, cassava plants never builds up canopy to completely cover the inter space even at its rank growth stage and thus gives increased returns from cassava based intercropping system due to lack of competition with inter crops (Anilkumar, 1984a, Anilkumar,1984b, Biju,1989).

Intercropping cassava and fodder grasses with extensive fibrous root system helps to reduce soil erosion, leaching of nutrients and decline in soil fertility. It also checks the growth of weeds, compared to pure crop cassava. Similarly the integration of legumes in cassava based cropping system can provide protection against runoff and erosion, and also at the same time can enhance the yield of succeeding crop due the nutritional contribution from the residues. Fodder legumes can contribute nitrogen to the soil by atmospheric N fixation, decay of dead root nodules or by mineralization of shed leaves. Including a tropical legume in fodder grass production system can provide the nitrogen required for the growth of grass and can also improve the quality of forage by increasing the protein content.

The association of arbuscular mycorrhizal fungi with plant roots, through acquisition of phosphates and other mineral nutrients from soil by the fungus is recognized as a key component of a healthy and productive agricultural system. Apart from increasing nutrient uptake, AM fungi are also found to improve the crop - water relations by improving the tolerance to water stress. Although AM fungi are recognized as beneficial symbionts, they are relatively unstudied due to their obligate biotrophy where by completion of their life cycle depends on their ability to colonize a host plant (Harrier and Watson, 2003).

With this back ground the present study is undertaken with the objective to find out a cassava based fodder production system which is economically sound, biologically productive with high land use efficiency and to asses the response of the system to AMF application.

2. REVIEW OF LITERATURE

Cassava is one of the major tropical tuber crops which is well suited for intercropping with short duration crops. Several experiments have been conducted to determine the best intercrops for cassava, as well as the best planting arrangements. The importance and beneficial effects of Vesicular Arbuscular Mycorrhizae in cassava and fodder crops is well documented. The relevant literature collected, pertaining to the above topics are reviewed here under.

2.1 INFLUENCE OF FODDER INTERCROPPING ON THE GROWTH ATTRIBUTES AND YIELD OF CASSAVA

2.1.1 Height of cassava

Height of cassava was significantly influenced by intercropping with fodder cowpea and the maximum plant height of cassava was recorded when cassava was planted in normal row with fodder cowpea as intercrop (Anilkumar et al., 1990). Prabhakar and Nair (1992) observed that highest plant height was attained by sole crop of cassava than intercropped cassava in a cassava – groundnut intercropping system. Studies on cassava based intercropping system in Salem revealed that cassava intercropped with black gram resulted in maximum plant height (Balakrishnan and Thamburaj, 1993). The trial conducted at Ibadan, to determine the effects of intercropping with maize on micro-environment, growth and yield of cassava revealed that inclusion of maize with cassava increased plant height of cassava (Olasantan et al.,1995).

Okoli et al.(1996) observed significant reduction in height of cassava as a result of intercropping with cowpea. The results of an experiment conducted by Osundare and Agbola (2003) to determine the effects of different intercropping systems like sole cassava, cassava/ maize, cassava/ maize/ sweet potato and cassava/ cocoyam/ sweet potato on the performance of cassava showed that height of cassava was significantly reduced by intercropping. Amanullah et al., 2006a reported that intercropping in cassava reduced the height of cassava plant up to 180 DAP and the reduction in plant height being more by intercropping fodder cowpea at early stages.

2.1.2 Number of leaves

In a cassava – groundnut intercropping system, sole crop of cassava produced more number of leaves than intercrop cassava (Prabhakar and Nair, 1992).

2.1.3 Leaf Area Index

LAI, girth of stem and plant spread was found to be significantly influenced when cassava was intercropped with fodder cowpea (Anilkumar et al., 1990). Olasantan et al. (1995) observed a reduction in the leaf area index by intercropping cassava with maize. The depression of early cassava growth by vigorous maize resulted in reducing LAI of cassava when intercropped with maize (Olasantan et al., 1997). Significant reduction in cassava leaf area by intercropping was observed by Osundare and Agbola (2003) in an experiment conducted to determine the effects of different intercropping systems like sole cassava, cassava/ maize, cassava/ maize/ sweet potato and cassava/ cocoyam/ sweet potato on the performance of cassava. Sole cassava registered higher leaf area index than cassava intercropped with either fodder cowpea or fodder maize up to 120 days after planting and afterwards both sole cassava and cassava intercropped with cowpea registered comparable LAI (Amanullah et al., 2006a).

A trial was conducted in 2004/05 and 2005/06 cropping seasons to determine the effect of cowpea planting density on growth, yield and productivity of component crops in cowpea/ cassava intercropping system. It was found that the leaf area index (LAI) of cassava was highest with the highest cowpea planting density of 8000 plants ha^{-1} (Njoku and Muoneke, 2008).

2.1.4 Number of tubers $plant^{-1}$

There was no influence on the number of roots $plant^{-1}$, tuber number plant $^{-1}$ in cassava due to intercropping with fodder cowpea (Anilkumar et al., 1990). Balakrishnan and Thamburaj (1993) obtained highest number of tubers in cassava when intercropped with black gram. The number of cassava roots produced was significantly reduced as a result of intercropping with cowpea. But the number of cassava roots increased significantly as time of introduction of cowpea into cassava plots was delayed (Okoli et al., 1996).

Osundare and Agbola (2003) observed that number and weight of fresh tubers of cassava was significantly reduced by intercropping in an experiment conducted to determine the effects of different intercropping systems like sole cassava, cassava/ maize, cassava/ maize/ sweet potato and cassava/ cocoyam/ sweet potato on the performance of cassava.

2.1.5 Length of tuber

Length of tuber was not significantly reduced by intercropping cassava with fodder cowpea (Anilkumar et al., 1990). The results of an experiment conducted by Osundare and Agbola (2003) to determine the effects of different intercropping systems like sole cassava, cassava/ maize, cassava/ maize/ sweet potato and cassava/ cocoyam/ sweet potato on the performance of cassava showed that tuber length and stem girth of cassava was significantly reduced by intercropping.

2.1.6 Girth of tuber

Anilkumar et al.(1990) reported that there was no significant influence on girth of tuber in a cassava – fodder cowpea intercropping system under rainfed conditions compared to sole crop.

2.1.7 Utilisation index

In a cassava – fodder cowpea intercropping system utilisation index, rind to flesh ratio and dry matter content of cassava were not significantly influenced and maximum value of utilisation index was recorded when cassava was planted in skipped rows with fodder cowpea in inter spaces (Anilkumar et al., 1990).

2.1.8 Tuber yield

Bai et al. (1990) reported highest tuber yield of cassava from intercropping with groundnut + *Vigna unguiculata*, followed by cassava/ *Vigna unguiculata* and then cassava/ groundnut. Ezumah (1990) obtained higher tuber yield by sole cassava when intercropped with maize. Bridgit et al.(1992) obtained tuber yield of 19.6 t ha^{-1} for cassava when grown alone and 20.64 t ha^{-1} when intercropped with groundnut. In a study conducted by Karnik et al. (1993) by intercropping legumes and vegetables with rainfed cassava, cassava monoculture gave significantly highest tuber yield (26.16 t ha^{-1}) followed by cassava – cowpea (23.26 t ha^{-1}) and cassava + black gram (22.66 t ha^{-1}).

Tuber yield of cassava was not adversely affected by intercropping with different cowpea varieties. This indicates that cowpea can be grown as a successful intercrop in cassava which is probably due to short duration of cowpea the cycle of which will be completed even before tuber initiation (Savithri and Alexander, 1995). Leihner et al. (1996) conducted a study to asses the soil conservation effectiveness and crop productivity of forage legumes intercropping with cassava and found that, erosion was greater with forage legume intercropping than with cassava sole cropping in the first cropping period but once well established and uniformly distributed, under sown legumes controlled erosion effectively, though yields of cassava were depressed by 40% or more. He suggested that, lower cassava yields due to reduced cropping area and competition from the grasses could be compensated by the production of valuable forage and by increasing cassava planting density. Sheela et al. (1996) reported that cassava yield was not adversely affected by intercropping with cowpea. Cassava root yield increased with increased cowpea population density (Eke-Okoro et al., 1999; Jagtap et al., 1998).

Udoh and Ndaeyo (2000) observed that fresh root yield of sole cropped cassava was significantly higher than the yield cassava intercropped with maize and cowpea. Dung et al. (2005) reported that intercropping with flemingia reduced cassava yields by 13.8 percent (roots) and 4.1 percent (foliage) respectively in the first year, but increased them by 40.6 percent and 30.6 percent respectively in the second year. In a cassava intercropping system with *Brachiaria sp* a tremendous increase in cassava yield was noticed, (as long as brachiaria and cassava have been intercropped for at least 1 year) explained by the improvement of soil structure by brachiaria roots, which benefited cassava. Cassava yield was multiplied by 2.4 on average: when yield ranged 4.5 - 13.0 t ha^{-1} in pure stand, cassava associated to brachiaria produced 11.0 - 30.0 t ha^{-1}, without any fertilizer application (Charpentier et al., 2006).

Amanullah et al. (2006a) observed highest tuber yield in sole cropped cassava followed by cassava intercropped with cowpea, which was comparable with sole cassava. Cassava intercropped with cowpea decreased the root yield by 11 to 17 percent (Polthane et al., 2007). Amanullah et al. (2007a) pointed out that intercropping short duration crops like legumes did not affect the growth and yield of tubers in cassava significantly. Njoku and Muoneke (2008) reported highest tuber yield in cassava when intercropped with cowpea with a planting density of 80, 000 plants ha^{-1}.

2.2 INFLUENCE OF FODDER INTERCROPPING ON PAIRED ROW PLANTED CASSAVA

According to Anilkumar et al. (1990) highest tuber yield of cassava was obtained in a cassava - fodder cowpea intercropping system when sowing was done in paired rows (60/90 x 75 cm) with 50 kg N + 50 kg P + 50 kg K ha^{-1}. A field trial conducted by Bai et al.(1992b) to evaluate the influence of planting geometry and double intercropping in rainfed cassava under homestead farming systems of southern Kerala, revealed that there was no significant difference in yield between cassava planted uniformly (0.9 m x 0.9 m) or in paired rows (1.35 m x 0.9 m x 0.45 m). The yield data for three years indicated that pure crop of cassava in the normal or paired rows were on par with intercropped treatments of same geometry. Among the intercropped treatments cassava planted in paired rows and intercropped with fodder cowpea with 100% normal recommended dose registered maximum tuber yield (Savithri and Alexander, 1995). Sheela et al.(1996) evaluated the influence of cassava planted in normal, paired or skipped row planting patterns and intercropped with cowpea, *Vigna unguiculata* cv C-152, and found that planting cassava in normal or paired rows gave higher yield than skipped row planting.

2.3. INFLUENCE OF INTERCROPPING ON THE GROWTH ATTRIBUTES AND YIELD OF FODDER CROPS

2.3.1 Height of the plant

Height of fodder cowpea was significantly influenced by the planting geometry (normal or paired row planting) in a cassava - fodder cowpea intercropping system. (Anilkumar et al., 1990). In a cassava – groundnut intercropping system, plant height of groundnut was not significantly influenced either by spatial adjustment (normal spacing or wide row spacing) of cassava or by planting density of groundnut (2 rows or 4 rows or 5 rows) (Prabhakar and Nair, 1992). Highest plant height was recorded by pure crop of cowpea compared to intercropped ones in a cassava - fodder cowpea intercropping system (Sheela et al., 1996).

Paired row planting of BN Hybrid recorded maximum plant height of BN Hybrid and the intercrop cowpea. Mean height of the BN Hybrid increased significantly in presence of legume intercrop (Jayakumar, 1997). In a field study conducted to assess the effect of grass and legume intercropping on the biomass yield the mixture of guinea grass with rice bean significantly increased the height of grass (Ullah et al., 2007). Kumari et al. (2008a) reported that hybrid napier inter planted with drumstick recorded significantly higher plant height throughout the crop growth period.

2.3.2 Number of tillers

Planting geometry (normal or paired row planting) had no significant influence on number of branches and plant spread of fodder cowpea when intercropped with cassava under rainfed condition (Anilkumar et al., 1990). Prabhakar and Nair (1992) noticed that the number of leaves and number of branches per plant of groundnut were not affected by spatial arrangement (normal spacing or wide row spacing) of cassava or plant density of groundnut (2 rows or 4 rows or 5 rows).

Jayakumar (1997) observed significantly more number of tillers in BN hybrid intercropped with legume under paired row planting. He observed that planting under paired row system produced more number of branches in fodder cowpea. The number of tillers clump^{-1} was higher in sole crop and reduction in number of tillers was observed when hybrid napier was inter-planted with drumstick (Kumari et al., 2008a).

2.3.3 Leaf Area Index

Njoku and Muoneke (20080 reported that cowpea produced highest LAI when intercropped at highest planting density (80 000 plants ha^{-1}) with cassava.

2.3.4 Leaf: Stem ratio

Jayakumar(1997) reported that growing fodder cowpea and lablab bean along with BN hybrid had no significant effect on leaf: stem ratio of the grass in a BN hybrid - legume intercropping system. Pure crop of BN hybrid recorded highest L: S ratio. There was no significant influence of spatial arrangement (normal or paired row planting) on the leaf: stem ratio of fodder cowpea intercropped in cassava under rainfed conditions (Anilkumar et al., 1990).

2.3.5 Green fodder yield

Pure crop of fodder cowpea recorded highest green fodder yield compared to intercropped ones in a cassava - fodder cowpea intercropping system (Anilkumar et al., 1990). Gill et al.(1990) observed that hybrid napier planted in paired rows with subabul (1:1 ratio) gave the highest total fresh fodder yields compared with yield in pure stands or other mixed stands. Jayakumar(1997) concluded that the paired row planting produced maximum tonnage of green fodder yield (41.35 t ha^{-1}) in a BN hybrid - legume intercropping system. Green fodder yield increased to the tune of 7.814 t ha^{-1} due to fodder cowpea and lablab bean intercropping compared to pure crops.

Raising fodder cowpea as an intercrop of cassava, planted in normal or paired rows is advantageous to enhance the fodder production without reducing the tuber yield of cassava (Savithri and Alexander, 1995). Pure crop of fodder cowpea recorded highest green fodder yield compared to intercropped ones in a cassava - fodder cowpea intercropping system (Sheela et al., 1996).

Choubey et al. (1997) reported that intercropping *Brachiaria brizantha* with *Vigna umbellata* gave the highest green fodder yield. Reddy, and Naik, 1999 revealed that hybrid napier intercropped with cowpea produced the highest mean green forage yield of 33.6 t ha^{-1}.

Among the annual fodder legumes, cowpea was found to be the best intercrop for hybrid napier with a green fodder yield of 136.94 t ha^{-1} (Lakshmi et al., 2002). A reduction in green fodder yield was observed by Gopalan et al. (2003) when pearl millet – napier grass hybrid was intercropped with *Desmanthus virgatus.* Njoka-Njiru et al. (2006) observed that legumes improved the yield fodder grasses and the overall total herbage yield of the mixture was higher than sole fodder grasses.

Katoch and Marwah (2006) reported that hybrid napier intercropped with soybean in the *kharif* season, and oats, peas and sarson (*Brassica campestris* var. *sarson)* in the *rabi* season produced the highest green biomass of 87.64 t ha^{-1}. Kumari et al. (2008b) noticed a reduction in green forage yield when hybrid napier was grown as an intercrop in drumstick.

2.3.6 Dry fodder yield

In a trial conducted by Gill and Gangwar (1990) for the evaluation of intensive forage production system under guava plantation, pure crop of hybrid napier recorded maximum dry matter yield followed by hybrid napier + cowpea and guinea grass + cowpea. Pure crop of fodder cowpea recorded highest dry fodder yield compared to intercropped ones in a cassava - fodder cowpea intercropping system (Sheela et al., 1996).

Intercropping *Brachiaria brizantha* with *Vigna umbellata* gave the highest dry matter yield (Choubey et al. 1997). Dry fodder yield increased to the tune of 2.03 t ha^{-1} due to legume intercropping compared to pure crops in a BN hybrid - legume intercropping system (Jayakumar, 1997). He also concluded that legume intercropping has favourable influence on dry matter production of grasses. Fodder cowpea was found to be the best intercrop for hybrid napier with a dry fodder yield of 50.10 t ha^{-1} (Lakshmi et al., 2002).

In a field experiment conducted to determine the effect of intercropping perennial forage legumes like *Stylosanthes hamata, Centrosema pubescens* and *Glycine wighti* in pasture grasses *Cenchrus ciliaris, Chrysopogon fulvus* and *Paspalum notatum* for sustainable fodder production, the fodder yield of the grasses was found to be increased by the legumes (Reddy et al., 2004). Kumari et al. (2008b) noticed a reduction in dry forage yield when hybrid napier was grown as an intercrop in drumstick.

2.4. INFLUENCE OF CASSAVA - FODDER INTERCROPPING ON THE LAND USE EFFICIENCY AND BIOLOGICAL EFFICIENCY

In a trial conducted by Gill et al. (1990) hybrid napier (*Pennisetum purpureum* X *P. americanum)* and subabul (*Leucaena leucocephala*) were planted in pure stands, or mixed stands in 1:1 ratio in alternate rows or paired rows (2 rows of each crop), or mixed in the same row in 1:2 or 2:1 ratios, the highest values of relative crowding coefficient (4.8-6.02) and land equivalent ratio (1.36-1.39) was obtained under paired row planting system. The land equivalent ratio was highest (2.14) when cassava (uniform planting) was intercropped with cowpea (Bai et al., 1992a). Paired row planting of cassava intercropped with cowpea produced the highest land equivalent ratio (1.70) (Bai et al.,1992b).

Biological advantage of intercropping cassava with legumes decreases with the legumes growth duration, which should not exceed 90 days (Mutsaers et al.,1993). Paired row planting in a BN hybrid – legume intercropping system was significantly superior to normal row planting and recorded highest aggressivity and LER values (Jayakumar, 1997). According to Dapaah et al. (2004) aggressivity value of cassava in a cassava intercropping system in relation to maize, soybean or cowpea were all positive indicating cassava as a stronger competitor in the mixture.

The cassava intercropped with cowpea Amanullah et al. (2006b) registered higher tuber equivalent yield and LER than other systems. Cassava, being a long season wide spaced crop with slow initial growth and development, intercropping of a short duration crop like legumes may increase the biological efficiency as a whole by way of better nutrient efficiency and better weed control.(Amanullah et al., 2007a).

Cassava - cowpea intercropping system increased the land use efficiency by 72-76 percent over sole cropping (Polthane et al., 2007). Njoku, and Muoneke (2008) noted that the relative yield total, expressed as land equivalent ratio of the two crops was greater than 1.0 in a cassava - cowpea intercropping system. The highest land use efficiency was obtained by intercropping cassava and maize, with cassava planted in a double row spacing of 1.6 m x 0.5 m x 0.6 m and maize in a single row spacing of 0.8 m x 0.21 m or two rows of maize spaced at 0.4 m x 0.42 m between the double rows of cassava, with maize sown on cassava emergence (Streck et al., 2009).

2.5. INFLUENCE OF CASSAVA - FODDER INTERCROPPING ON THE QUALITY OF FODDER CROPS

In a hybrid napier - legume intercropping system maximum crude protein was obtained when the grass was grown under paired row system of planting. Legume intercropping resulted in maximum crude protein yield. But planting geometries had no significant effect on crude protein content of cowpea but a slightly higher trend was noticed when grown under paired row system of planting (Jayakumar, 1997). Tripathi et al. (1997) obtained higher content of crude protein when maize was intercropped with cowpea. Increase in crude protein content of napier grass associated with leguminous shrubs like calliandra and sesbania from 11.3 to 17.8 percent was reported by Niang et al. (1998).

Reddy and Naik (1999) obtained a crude protein yield of 916.0 kg ha^{-1}, when hybrid napier was intercropped with cowpea. Enhancement in crude protein was observed by Gopalan et al. (2003) when pearl millet – Napier hybrid grass was intercropped with *Desmanthus virgatus*.

Njoka-Njiru et al. (2006) observed that it was possible to produce high quantity of livestock feed of higher nutritional quality by incorporating a legume in a fodder grass production system. The results further indicated that there was a significant gain in crude protein content by inclusion of legumes in napier grass thus improving the herbage value and digestibility. Hybrid napier and its mixture with soybean had higher crude protein content and lower amounts of lignin and silica. (Katoch and Marwah, 2006).

2.6. INFLUENCE OF CASSAVA - FODDER INTERCROPPING ON SOIL CHARACTERS

Thamburaj (1991) reported that the N, P, K content of the soil was improved due to raising of legumes in cassava. Higher content of N, P, and K was recorded in plots where lablab bean was raised as an intercrop of BN hybrid than cowpea as intercrop (Jayakumar, 1997).

In a cassava - peanut intercropping system in terms of nutrient balance of soil when peanut stover was incorporated into the soil, cassava - peanut intercropping at different row arrangement produced less negative balance for N and K and positive balance for P than that of sole cassava (Polthane et al., 1998).

In a study conducted by Amanullah et al. (2007b) the depletion of soil nutrients was lesser in sole cassava followed by cassava intercropped with cowpea.

2.7. INFLUENCE OF CASSAVA - FODDER INTERCROPPING ON UPTAKE OF NUTRIENTS

Bridgit et al. (1992) reported that intercropping cassava with groundnut cv. TMV-2 had no significant effect on cassava leaf, petiole, stem and tuber N contents but it increased N uptake plant^{-1}. Cassava leaf K content and K uptake plant^{-1} were increased by intercropping. The trial conducted at Ibadan to determine the effects of intercropping with maize on micro-environment, growth and yield of cassava revealed that inclusion of maize with cassava decreased nutrient uptake in cassava (Olasantan et al., 1995).

In a study conducted by Jayakumar (1997) intercropping hybrid napier with lablab bean resulted in maximum uptake of N (113.10 kg ha^{-1}) and P (16.48 kg ha^{-1}). Hybrid napier and cowpea at different planting geometries has significant effect on N and K uptake and highest value was recorded by paired system of planting. According to Polthane et al. (1998) cassava – peanut intercropping system removed more N, P, and K than sole cassava. Polthane and Koltchasatit (1999) reported that total N, P, K uptake of cassava and mung bean grown together under intercropping patterns was similar to that of sole crop of cassava.

Ricaurte et al. (2000) observed the presence of cover legumes not only reduced soil erosion but also improved potassium acquisition by cassava. In a study conducted by Amanullah et al. (2007b) sole cassava had higher uptake of all nutrients (N, P and K) followed by cassava intercropped with cowpea.

2.8 INFLUENCE OF CASSAVA - FODDER INTERCROPPING ON ECONOMICS OF THE SYSTEM

The highest net income was obtained when cassava was intercropped with cowpea by Bai et al. (1990). Sheela and Kunju (1990) suggested that for getting maximum net return from cassava based intercropping system, groundnut can be raised as an intercrop with a fertilizer level of 50 kg N + 62.5 kg P_2O_5 + 62.5 kg K_2O ha^{-1}. Even though the intercrops reduced yields of main crop cassava, the reduction was compensated by the intercrop yield and further increased the net profit of farmer. Kumar and Ravindran (1991) conducted a trial to determine the economics of intercropping short duration legumes and vegetables with cassava and found that intercropping cassava with *Phaseolus vulgaris* with NPK application to both crops, gave highest tuber yield of 21.6 t ha^{-1} and the highest net returns, compared with intercropping groundnut, *Vigna unguiculata* or cucumbers.

The highest benefit: cost ratio was obtained when paired rows of cassava were intercropped with cowpea (Bai et al*.,* 1992b). Prabhakar and Nair (1992) noticed that highest gross return was obtained from cassava in wide rows intercropped with five rows of groundnut. Studies on cassava based intercropping system in Salem revealed that cassava intercropped with blackgram produced highest B: C ratio. (Balakrishnan and Thamburaj, 1993).

Savithri, and Alexander (1995) obtained highest gross returns and cost: benefit ratio when cassava was intercropped with cowpea cv. Pusa-2 or New Era. The monetary returns ha^{-1} is appreciably higher under cassava intercropping systems, and is mainly due to the higher value of intercrops (Prabhakar et al., 1996). B: C ratio of 2.5 was obtained when hybrid napier was intercropped with fodder cowpea (Lakshmi et al., 2002). Amanullah et al.(2007a) suggested that intercropping in cassava could fetch additional income and since cassava being a wide spaced and initially slow growing crop, it could provide ways to better use the physical resources (solar radiation, mineral nutrients and water) and provide high labour productivity than sole cropping and reduce risk compared with sole cropping.

In economic terms, cassava - cowpea intercropping gave higher net returns over sole cropping (Polthane et al., 2007). Njoku and Muoneke (2008) noticed that cassava intercropped with 80000 cowpea plants ha^{-1} gave higher monetary returns than when intercropped with other population densities of cowpea or in monoculture of the two crops. Similarly, cowpea at highest population density gave the highest monetary returns.

2.9 INFLUENCE OF AMF ON THE GROWTH ATTRIBUTES AND YIELD OF CASSAVA

2.9.1 Plant height of cassava

Sivaprasad et al.(1990) reported maximum plant height in cassava, by inoculation with VAM fungi, *Glomus fasciculatum*. Dual inoculation with *Glomus aggregatum* and *Glomus mosseae* induced maximum plant height in cassava compared with inoculation of *Glomus aggregatum* and *Glomus mosseae* and *Gigaspora albida* (Ganesan and Mahadevan, 1994). Salami, and Osonubi (2006) noticed increased plant height in a maize – cassava alley cropping system by AMF inoculation. Inoculation of VAM fungus increased the height of the plant significantly as recorded at 2MAP. The trend was similar at other sampling periods even though the data was not statistically significant.

2.9.2 Number of Leaves

Inoculation of Vesicular Arbuscular Mycorrhizae resulted in better leaf production in cassava which may be due to the increased uptake of nutrients (Narayanan, 1991). Oyetunji and Osunobi (2007) concluded that alley cropping can bring sustainable cassava production if integrated with AMF. The cassava leaf production was significantly higher in mycorrhizal inoculated plots than non inoculated counterparts.

2.9.3 LAI

The results of the trial conducted by Fagbola et al. (1998) to asses the growth of cassava as affected by alley cropping and mycorrhizal inoculation indicated increase in LAI of both alley and sole-cropped cassava inoculated with *Glomus clarum*.

2.9.4. Tuber yield

Highest tuber yield of cassava was obtained in plots where phosphorus was given along with mycorrhizal inoculation (Potty, 1990). Sivaprasad et al. (1990) observed highest shoot and root dry weight in cassava when inoculated with *Glomus fasciculatum*. The dry matter production of cassava was increased due to VAM association established at early stages of crop growth (Narayanan, 1991).

Results of alley cropping trials revealed that yield of cassava were high in areas with greater VAM spore density (Atayese et al., 1993). Application of VAM + Rhizobium was most effective in terms of yield and net returns in cassava + stylosanthus mixture (Sreedurga, 1993). Mycorrhizal inoculation had led to an increase in the fresh tuber yield of both the alley and sole-cropped cassava (Fagbola et al., 1998).

Oyetunji et al (2003) concluded that due to positive growth and yield, use of AM fungus is beneficial for greater productivity of cassava. The yield of cassava increased to the tune of 3 t ha^{-1} by application of VAM (Ramanathan and Anandaraman, 2003). Okon and Osonubi (2005) conducted a study on effect of arbuscular mycorrhizal fungi on the tuber yield of alley cropped cassava and found that highest fresh tuber yield was obtained with AMF inoculation.

Miranda et al. (2005) pointed out that cassava (*Manihot esculenta*) plants are highly dependent on arbuscular mycorrhiza for optimum growth. Higher plant growth and root yield are attained and applied inputs are better used when the cassava plants are inoculated with mycorrhizae. The increase in cassava yields brought about by the AM fungi ranged between 20.6-167 percent (Oyetunji and Osonubi, 2007).

2.10. INFLUENCE OF AMF ON THE GROWTH ATTRIBUTES AND YIELD OF FODDER CROPS

2.10.1 Plant height

Chhabra et al. (1990) observed that VA mycorrhizal inoculation increased plant height, in cowpea plants compared with the uninoculated controls. Siqueira et al. (1990) opined that *Brachiaria decumbens* plants inoculated with mycorrhizae grew better than non-mycorrhizal ones in unlimed soil and with 4.5 or 6.0 g lime/kg soil. In fodder cowpea plants VAM inoculation led to an increase in plant height (Kavitha, 1996). George (1996) observed that guinea grass and congo signal responded positively and significantly to VAM inoculation. Under VAM inoculation the plants were taller than those under absolute control.

Uma and Rao (1994) reported an increase in shoot length of black gram and green gram due to inoculation with VA mycorrhiza. Cowpea inoculated with mycorrhizal fungi showed increased plant height (Gupta et al., 1999). Plant height of guinea grass was not significantly influenced by inoculation of VAM (Singh et al., 2000). Calderon and Gonzalez (2007) observed highest plant height in guinea grass when inoculated with AMF. Mali et al. (2009) reported that vesicular arbuscular mycorrhizae, *Glomus fasciculatum* significantly enhanced the stem length in cowpea plants.

2.10.2 Number of tillers

Under VAM inoculation guinea grass and congo signal had significantly higher number of tillers than those under absolute control (George, 1996). Calderan and Gomez (2007) observed highest tiller diameter in guinea grass when inoculated with AMF.

2.10.3 Number of leaves

Geethakumari et al. (1990) reported that number of leaves hill^{-1} of ragi was positively influenced by mycorrhizal inoculation. Lu and Koide (1994) observed that in general mycorrhizal plants had much greater leaf area, leaf weight and also more number of leaves. VAM inoculation helped for greater utilization of environmental resources and increased the number of leaves in fodder cowpea plants (Kavitha, 1996).

2.10.4 Green fodder yield

Napier bajra hybrid and *Brachiaria brizantha* recorded an increase of 10% and 12% yield over control respectively when inoculated with VAM (Hazra, 1994). Under VAM inoculation green fodder yield of guinea grass increased significantly over absolute control (George, 1996). Kavitha (1996) observed the increase in yield of fodder cowpea by inoculation of VAM to the companion crop maize. Singh et al. (2000) pointed out that seed inoculation of guinea grass with VAM produced the highest green forage yields. According to Kahlon et al. (2006) application of 50 kg P + 20 kg S + 10 kg Zn ha^{-1} + PSB + VAM recorded the highest haulm (2942.0 kg ha^{-1}) and grain yield (2208.0 kg ha^{-1}) in fodder cowpea plants. Application of *Glomus fragilis* increased yield in napier grass (Weinching, 2007).

2.10.5 Dry fodder yield

Inoculation of soybean with *Glomus fasciculatum* or indigenous VA mycorrhizal fungi increased the dry matter accumulation in plants (Singh, 1990). Hazra (1994) observed 24 percent increase in dry fodder yield of guinea grass through mycorrhizal association. Souza et al. (1999a) observed an increase in dry matter production of *Brachiaria brizantha* with mycorrhizal inoculation. Inoculation of AMF increased both shoot and root dry weight in *Brachiaria decumbens*, *Brachiaria brizantha* and *Panicum maximum*. All the grass species showed the highest mycorrhizal dependency for dry matter production (Kanno et al., 2006). Silva et al. (2006) observed an 84 percent increase in dry matter yield of Brachiaria grass when inoculated with AMF. Highest dry matter yields were obtained in guinea grass with inoculation of AMF (Calderon and Gonzalez, 2007).

2.11. INFLUENCE OF AMF ON QUALITY OF FODDER CROPS

George (1996) reported that crude protein content of congo signal was not significantly influenced by inoculation with VAM. Crude protein content of above ground parts of *Brachiaria brizantha* increased with AMF inoculation (Souza et al., 1999). Seed inoculation of guinea grass with AMF produced highest crude protein yields (Singh et al., 2000).

2.12. INFLUENCE OF AMF ON UPTAKE OF NUTRIENTS

Howeler (1989) reported that cassava is very dependent on vesicular-arbuscular mycorrhizas (VAM), and this under natural conditions greatly increases P uptake. In soils with a good VAM population, cassava grows well at very low P levels; without VAM, the crop is very responsive to P fertilization and/or VAM inoculation. Inoculation with vesicular arbuscular mycorrhizae increased the N, P and K contents in cowpea plants significantly (Chhabra et al.,1990). There are indications that VAM hyphae are able to take up phosphate from soil solutions with low phosphate soil concentration more efficiently than simple roots (Barea, 1991).

Sivaprasad et al.(1991) indicated that uptake of P, K, Mg and Ca by cassava increased when inoculated with vesicular arbuscular mycorrhizae *Glomus fasciculatum*, *Glomus mosseae*, *Acaulospora morroweae*, *Glomus etunicatum* or *Glomus constrictum*, the first being the most effective. Vesicular arbuscular mycorrhizae are of particular importance for plant acquisition of P and other nutrients which are immobile in soil (Johansen et al., 1993). The phosphorus and potassium content were high in mycorrhizal inoculated fodder cowpea plants compared to uninoculated control (Kavitha, 1996).

Mycorrhizae are known to influence the host growth through enhanced nutrient uptake in general, phosphorus in particular. Mycorrhizal hyphae have the capacity to take up and deliver nutrients to the plant up to 80 percent plant P, 25 percent plant N and 10 percent plant K (Marschner and Dell, 1994). Osonubi et al. (1995) found that while VAM inoculation significantly increased the root uptake of N, P and K, the leaf uptake was not affected except for the uptake of P. VAM inoculation in cassava significantly enhanced cassava root dry weight indicating that an effective VAM fungus can be an agent of greater nutrient uptake in a competitive environment.

VAM inoculation was found to increase the uptake of all nutrients except manganese during the whole cropping period of guinea grass (George, 1996). Narayanan and Saifudeen (1996) concluded that the uptake of nutrients from the soil was higher in cassava plants inoculated with VAM fungi. Better intake of essential nutrients, including the difficultly absorbed elements like 'P' was facilitated by fast rates of infection by VAM fungi which ranged from 13 to 15 percent in the first month to more than 90 percent in many cases at third month. The concentration of nitrogen, phosphorus and potassium in young fully emerged leaves was significantly increased with VAM inoculation.

Souza et al. (1999b) noticed accumulation of P, K, Ca and Mg in the dry matter of aboveground parts with increasing P rate, and the effects were increased by the presence of mycorrhizal fungi. Graham and Abbott (2000) have reported increased VAM colonization at moderate or high soil P content reduced the carbon costs (photosynthate recruited to the AM fungi) without beneficial effects on plant nutrient status. Tholkappian et al.(2000) reported that increased root colonization by VAM augmented the uptake of nitrogen, potassium, phosphorus and other minor nutrients in cassava resulting in an increase in the yield.

Mycorrhiza enhances uptake of P, Zn, S and water and impart resistance to root diseases and helps plant under drought condition and is recommended for forest trees, forage grasses, maize, millets, sorghum, barley and leguminous crops (Thomas, 2003).

Shoot and root P concentration and total P uptake in *Brachiaria decumbens*, *Brachiaria brizantha* and *Panicum maximum* were improved by mycorrhizal association (Kanno et al., 2006). Calderan and Gonzalez (2007) reported that with the inoculation of guinea grass with AMF highest N, P, K content of biomass was observed.

VAM symbiosis enhances host roots ability to absorb less mobile/ soluble minerals like P Zn, Cu from soil. The improved mineral nutrition enhances plant growth as well as plant biomass and also influences partitioning of this material between root and shoot (Gupta et al., 2007). Mali et al. (2009) revealed that vesicular arbuscular mycorrhizae, *Glomus fasciculatum* significantly enhanced uptake of NPK in cowpea plants.

2.13. INFLUENCE OF AMF ON SOIL CHARACTERS

Fertilizer P for guinea grass can be fully substituted with VAM application (George 1996). Jacobsen (1994) suggested that mycorrhizae improved soil structure by their stabilizing effect on soil aggregates. Increased root biomass and greater quantity of microbial biomass in the rhizosphere resulted in the higher values of organic carbon in the soil under VAM inoculation (Marschner and Dell, 1994). Inoculation with VAM with fodder cowpea plants increased the P uptake and resulted in low available P status in the soil after experiment (Kavitha, 1996).

2.14. INFLUENCE OF AMF APPLICATION ON THE ECONOMICS OF THE SYSTEM.

Net monetary returns of cassava increased to the tune of Rs.30000 ha^{-1} by the application of VAM (Ramanathan and Anandaraman, 2003). Economic analysis revealed that VAM technology for congo signal and guinea grass was highly profitable in terms of net profit and B: C ratio (George, 1996).

Materials and Methods

3. MATERIALS AND METHODS

A field experiment was conducted to asses the bio and economic suitability of raising fodder grasses and legumes in the alleys of cassava for food - fodder production and to study the response of the system to AMF application at the Instructional Farm attached to the College of Agriculture, Vellayani during 2009. The materials used and methods adopted are detailed below.

3.1 MATERIALS

3.1.1 Experimental site

The experiment was conducted at the Instructional Farm attached to College of Agriculture, Vellayani. The farm is located at 8^o 5’N latitude, 76^o 9’E longitude and at an altitude of 29 m above MSL.

3.1.2 Soil

The soil of the experimental site was red sandy clay loam (Oxisol, Vellayani series). The soil physico chemical properties are given in Table: 1.

3.1.3 Season and Climate

The experiment was conducted at the Instructional Farm during the period from June 2009 to December 2009. The meteorological parameters such as rainfall, maximum and minimum temperature and evaporation rate recorded during the given period are given in the Appendix no: 1 and graphically presented in Fig No.1. The abstract of the weather data is given in the Table: 2.

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

Properties	Mean value	Method used
Physical properties		
1. Mechanical composition		
Coarse sand (%)	16.70	Bouyoucos Hydrometer method
Fine sand (%)	31.30	(Bouyoucos ,1962)
Silt (%)	25.50	
Clay (%)	26.50	
2. Bulk density (%)	1.375	Gupta and Dakshinamoorthy,1980
3. Water holding capacity (%)	21.50	Gupta and Dakshinamoorthy,1980
4. Porosity (%)	32.00	Gupta and Dakshinamoorthy,1980
Chemical properties		
Soil reaction(p^H)	5.2	p^H meter with glass electrode (Jackson,1973)
Available Nitrogen ($kg\ ha^{-1}$)	341 (medium)	Alkaline Permanganate method (Subbiah and Asija,1956)
Available Phosphorus ($kg\ ha^{-1}$)	50.35 (high)	Bray's colourimetric method (Jackson,1973)
Available Potassium ($kg\ ha^{-1}$)	99.76 (low)	Ammonium acetate method (Jackson,1973)
Organic Carbon (%)	0.83 (high)	Walkely and Black method (Jackson,1973)

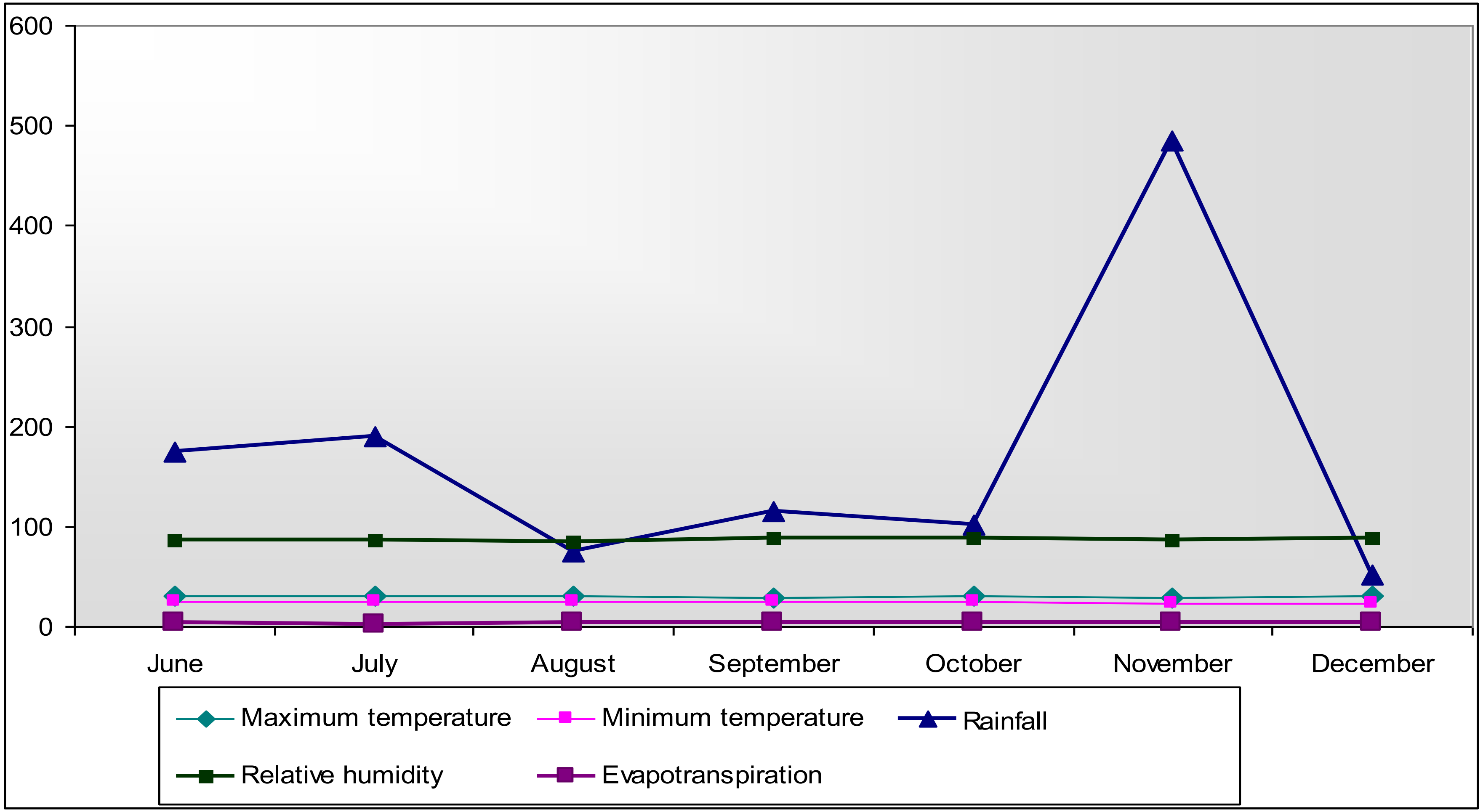


Fig.1 Weather conditions during the season (June 2009 to December 2009).

Table: 2 Abstract of the weather data during the experimental period (June 2009 to December 2009)

Weather elements	Range
Maximum temperature (°C)	29.6 - 30.7
Minimum temperature (°C)	23.7 - 24.2
Total rainfall (mm)	1191.9
Relative humidity (%)	84.6 - 88.1
Monthly evaporation (mm)	2.8 - 3.5

3.1.4 Crops and Varieties

3.1.4.1 Main crop - Cassava

The variety Vellayani Hraswa was used for the trial. Vellayani Hraswa is a high yielding variety with 5-6 months duration and very good cooking quality. Tubers contain 27.8 percent starch and 53 ppm cyanogen. The planting material required for the study was obtained from a farmer's field at Palappur who obtained his planting material from Instructional Farm, Vellayani.

3.1.4.2 Alley crops

3.1.4.2.1 Bajra Napier Hybrid

The BN hybrid variety Suguna, released by Kerala Agricultural University was used for study. Suguna is a profuse tillering variety with long broad leaves and pale green leaf sheath with purplish pigmentation, suitable for uplands in all seasons.

The slips of this variety required for the study was obtained from the Department of Agronomy, College of Agriculture, Vellayani.

3.1.4.2.2 Palisade grass

Palisade grass (*Brachiaria brizantha*) is a loosely tufted perennial with erect or slightly decumbent stems and flat leaves which are bright green and hairy. The slips of this grass for the trial were obtained from the planting material production unit of Western Ghat Development Project on 'Analysis of homestead based fodder production and interventions for economic milk production in the homesteads of Trivandrum district of Western Ghat region of Kerala' of the Department of Agronomy, College of Agriculture, Vellayani.

3.1.4.2.3 Fodder Cowpea

The Fodder cowpea variety COFC 8 was used for the investigation. COFC 8 is a semi spreading variety, erect in early stage, indeterminate type with luxurious growth. The variety is suitable for intercropping, with high green fodder yield, protein content and palatability. The seeds of this variety was obtained from Department of Forage crops Tamilnadu Agricultural University, Coimbatore.

3.1.5 AMF

The vermiculite based mycorrhizal inoculum containing infected roots and mycorrhizal spores was used for the study. The inoculum was purchased from the Department of Agricultural Microbiology, College of Agriculture, Vellayani.

3. 2. METHODS

3.2.1 Experimental Design and Lay Out

The experiment was laid out in Randomized Block Design with three replications. The lay out plan of the experiment is given in the Fig.2 and a detailed illustration of the crop arrangement as per treatments in Fig.3. The number of plants hectare^{-1} for each treatment is given in Table.3 and the general view of the experimental field is given in the Plate 1.

Table.3. Number of plants hectare^{-1} in each treatment.

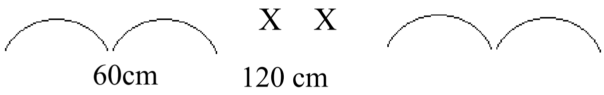
Treatments	Number of plants ha^{-1}			
	Cassava	BN hybrid	Palisade grass	Fodder cowpea
T_1	12345	18518	-	-
T_2	12345	18518	-	-
T_3	12345	-	18518	-
T_4	12345	-	18518	-
T_5	12345	-	-	111111
T_6	12345	-	-	111111
T_7	12345	18518	-	18518
T_8	12345	18518	-	18518
T_9	12345	-	18518	18518
T_{10}	12345	-	18518	18518
T_{11}	12345	-	-	-
T_{12}	-	27777	-	-
T_{13}	-	-	27777	-
T_{14}	-	-	-	222222

3.2.2 Treatments

The treatment details are furnished below and in Plates 2 and 3.

T_1: Cassava + B N Hybrid

T_2: Cassava + B N Hybrid + AMF

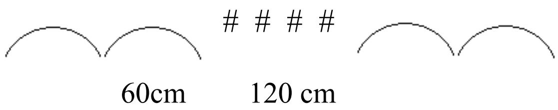


T_3: Cassava + Palisade grass

T_4: Cassava + Palisade grass + AMF

T_5: Cassava + Fodder cowpea

T_6: Cassava + Fodder cowpea + AMF

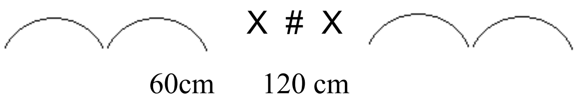


T_7: Cassava + B N Hybrid + Fodder cowpea

T_8: Cassava + B N Hybrid + Fodder cowpea + AMF

T_9: Cassava + Palisade grass + Fodder cowpea

T_{10}: Cassava+ Palisade grass +Fodder cowpea + AMF



T_{11}: Sole crop of Cassava

T_{12}: Sole crop of B N Hybrid

T_{13}: Sole crop of Palisade grass

T_{14}: Sole crop of Fodder cowpea

Number of replications: 3

Total number of plots: 42

Plot size

Gross plot: 5.4 m x 3.6 m

Net plot : 3.6 m x 1.8 m

Plate 1.General view of the experimental field

Cassava+BN hybrid

Cassava+Palisade grass

Cassava+Fodder cowpea

Cassava+Palisade grass + Fodder cowpea

Cassava+BN hybrid+Fodder cowpea

Plate 2 Treatments

Sole cassava

Sole B N hybrid

Sole palisade grass

Sole fodder cowpea

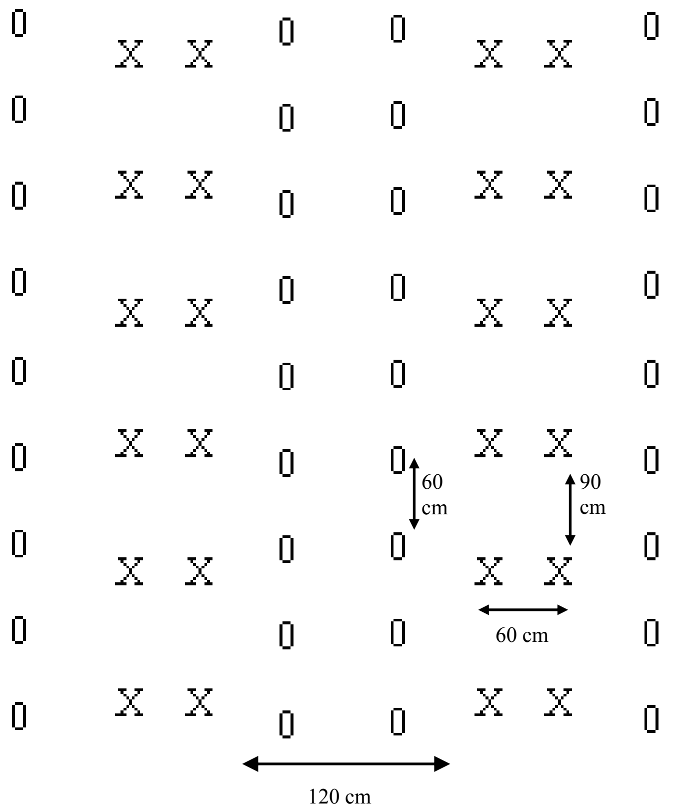
Plate 3 Treatments

→ N

T_{3}	T_{14}	T_{14}
T_{1}	T_{3}	T_{7}
T_{6}	T_{9}	T_{9}
T_{9}	T_{12}	T_{5}
T_{11}	T_{5}	T_{13}
T_{5}	T_{13}	T_{10}
T_{14}	T_{1}	T_{8}
T_{8}	T_{4}	T_{12}
T_{12}	T_{7}	T_{3}
T_{13}	T_{8}	T_{2}
T_{7}	T_{10}	T_{4}
T_{10}	T_{2}	T_{6}
T_{4}	T_{11}	T_{11}
T_{2}	T_{6}	T_{1}
R1	**R2**	**R3**

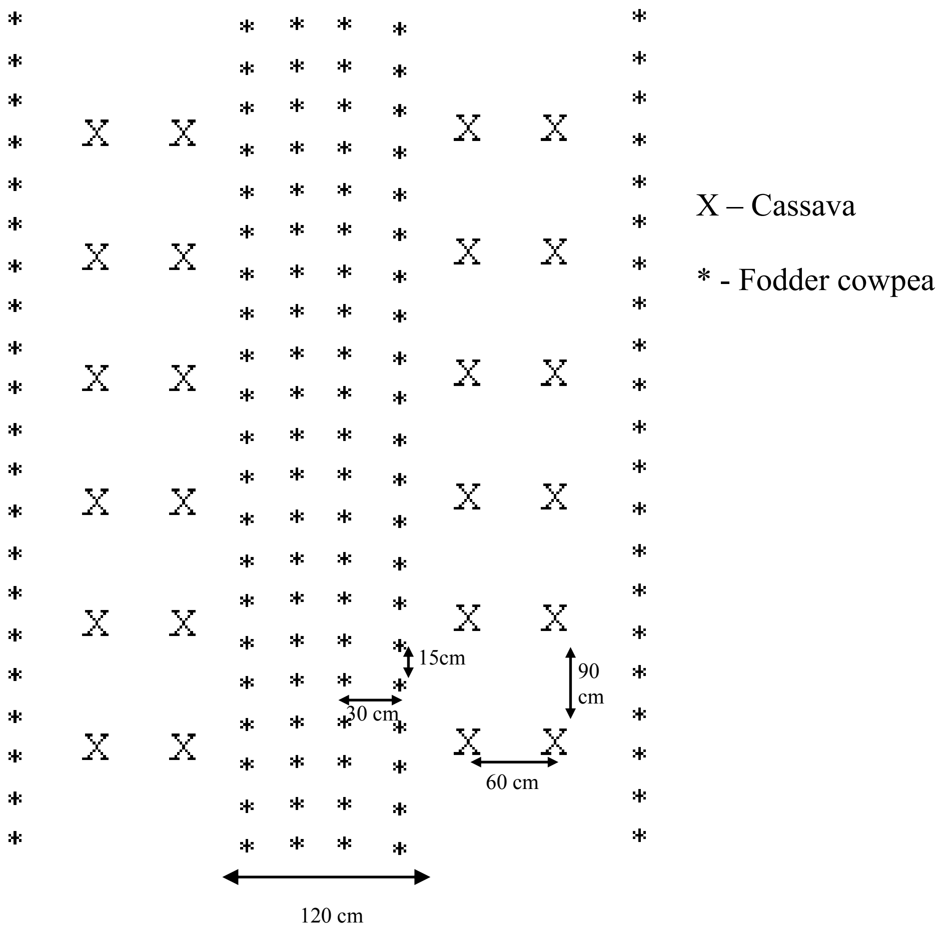
Fig: 2 Lay out plan of the experiment

Fig: 3 Detailed illustration of the crop arrangement in the different treatments.

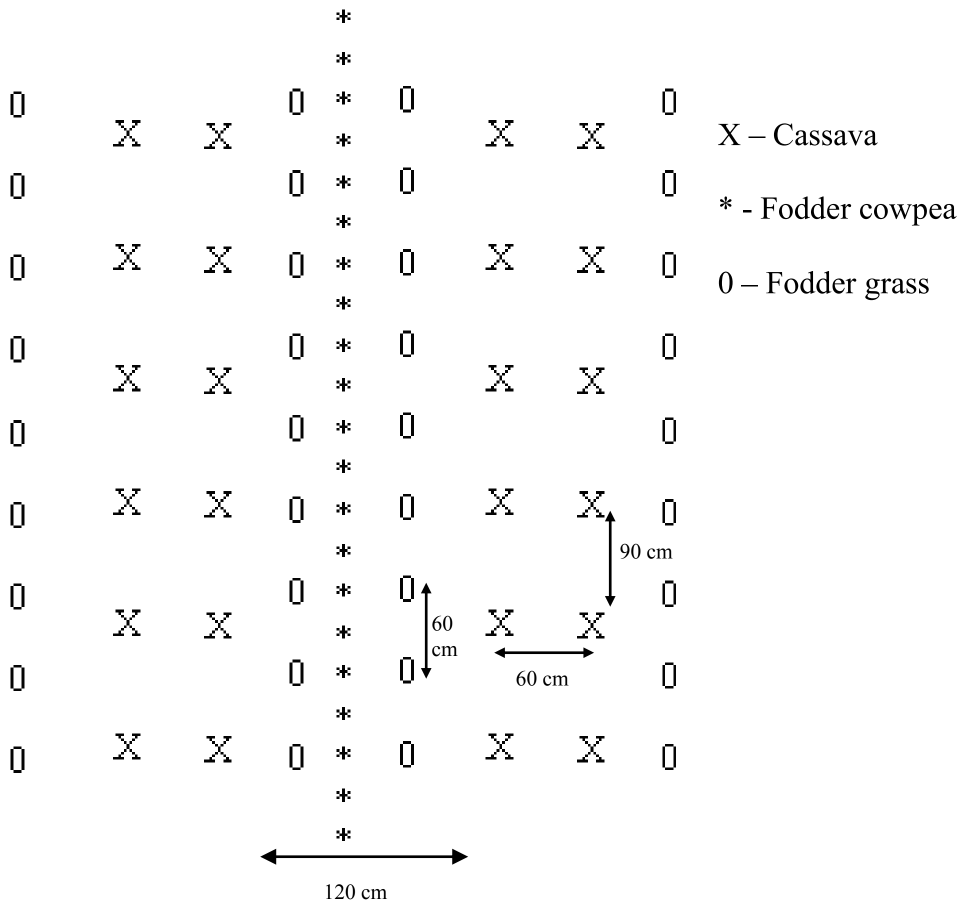


X – Cassava
0 - Fodder grass

Cassava + BN hybrid /palisade grass



Cassava + fodder cowpea



Cassava + fodder grass + fodder cowpea

3.2.3 Preparation of land

The experimental area was ploughed twice, clodes broken, stubbles removed and the field was laid out into blocks and plots. Mounds for planting cassava were taken at a spacing of 90 cm in paired rows of 120/60 cm. Channels for planting fodder grasses and fodder cowpea were taken in the interspaces of paired rows.

3.2.4 Manuring

A uniform dose of 12.5 t ha^{-1} of FYM was applied in the area allotted for planting cassava as basal and well incorporated in the soil before taking mounds. FYM @ 25 t ha^{-1} and 5 t ha^{-1} was applied in the channels taken for planting BN hybrid and palisade grass respectively and well incorporated in the soil. FYM @ 10 t ha^{-1} was applied in the rows taken for planting fodder cowpea and incorporated in the soil.

3.2.5 Fertilizer application

The fertilizer nutrients were applied in the form of Urea, Super phosphate and Muriate of potash for supplying N, P_2O_5 , K_2O respectively.

Fertilizer doses applied for cassava and alley crops were as follows

Crop	Recommended dose N, P_2O_5 , K_2O (kg ha^{-1})	Time of application
Cassava	100:100:100	$^1/_3$ N+ Full P + $^1/_3$ K – Basal $^1/_3$ N + $^1/_3$ K - 2 MAP $^1/_3$ N + $^1/_3$ K - 3 MAP
BN Hybrid	200:50:50	½ N + Full P + Full K – Basal

		½ N – 2 MAP
Palisade grass	150:50:50	½ N + Full P+ Full K - Basal ½ N - 2 MAP
Fodder cowpea	40:30:30	Full dose as basal

3.2.6 Preparation of AMF slurry

Slurry of the culture was prepared for dipping the fodder grass setts @ 3g inoculum per sett.

3.2.7 Preparation of planting material

Cassava setts of length 15- 20 cm were used for planting. AMF inoculum @ 5 g per sett was uniformly applied as a thin layer on the top of the mounds at the center as per treatments and cassava setts were planted in these mounds. Healthy cuttings of BN Hybrid with 2-3 nodes were taken and the basal portion was dipped in AMF slurry. The roots of the slips of palisade grass were dipped in the slurry of AMF and planted. In fodder cowpea plots with AMF application, AMF was applied as a thin layer in the channels taken for sowing the seeds of fodder cowpea so that, all developing roots passed through the inoculum(Plate 4).

3.2.8 Planting

3.2.8.1 Date of planting

Planting of cassava was done on 26-06-2009. Planting of the fodder grasses were done on 03-07-2009 (BN Hybrid and Palisade grass). The first crop of fodder cowpea was planted on 04-07-2009. After the harvest of the first crop of fodder cowpea the second crop was sown on 02-10-2009.


Inoculation of cassava


Inoculation of fodder grasses


Inoculation of fodder cowpea

Plate 4 AMF Inoculation

3.2.8.2 Planting Method

3.2.8.2.1 Cassava

Cassava was planted in paired rows with a spacing of 60/120x90 cm. That is 60 cm between two rows making a pair, 120 cm between two such paired rows and 90 cm between plants within a row. Cassava setts were planted upright on the top of the mounds, to a depth of 3-4 cm. Setts were planted above the thin layer of AMF in plots with AMF application.

3.2.8.2.2 Alley crops

Fodder grasses and fodder cowpea were raised in the alleys formed between paired rows of cassava.

Setts of BN hybrid were planted in the channels taken in the alleys of cassava @ 1 sett per hill, at a spacing of 60 cm x 60 cm. In the plots with AMF application slips treated with AMF were used for planting. Slips of palisade grass were planted in the channels taken in the alleys of cassava @ 2 slips per hill at a spacing of 60 cm x 60 cm. Slips treated with AMF were used for planting in the plots with AMF application.

Seeds of fodder cowpea were sown @ 2 seeds per hole at a spacing of 30 x 15 cm in the alleys of cassava as well as between the rows of fodder grasses as per the treatments. In AMF applied plots, seeds were sown just above the thin layer of AMF and then covered with soil.

3.2.9 After cultivation

Gap filling was done twenty days after planting. Excess sprouts were removed retaining only two healthy and vigorous shoots on appropriate stages.

Dried slips / setts of fodder grasses were removed and replaced with healthy ones according to the treatments. Thinning was done for fodder cowpea, one week after sowing and population was maintained uniform. Earthing up was done for cassava at 2 MAP. Intercultivation and hand weeding operations were done at monthly intervals.

3.2.10 Irrigation

The crops were raised under rainfed condition.

3.2.11 Plant protection measures

Necessary plant protection measures were taken against grass hopper attack on fodder cowpea by dusting Metacid 2 percent dust mixed with neem cake. Poison bait prepared by mixing Zinc phosphide with palayamkodan banana and dried fish were kept in the field against rat attack. Bromodialone (0.05 percent) cake was also kept in the field against attack of rats.

3.2.12 Harvest

Cassava was harvested at 184 DAP on 26-12-09. Two cuts were taken for BN hybrid and palisade grass with first harvest on18-09-09 (75 DAP) and second harvest on 23-11-09 (140 DAP). First crop of fodder cowpea was harvested on 28-08-09 (54 DAS) and second crop on 24-12-09(82 DAS of second crop).

3.3. OBSERVATIONS RECORDED

3.3.1 Biometric observations

Cassava

Observations were taken from four plants randomly selected from the net plot.

3.3.1.1 Height of the plant

Height of each plant was measured from the base of the sprouts to the tip of the terminal bud at bimonthly intervals.

3.3.1.2 Number of leaves plant^{-1}

The number of fully opened leaves retained in the plants was recorded at bimonthly intervals till harvest.

3.3.1.3 Leaf area index (LAI)

LAI was computed by using the length x width method suggested by Gomez (1972).

$$LAI = \frac{K\ (L \times W) \times \text{Number of leaves plant}^{-1}}{\text{Area occupied by the plant}}$$

K = adjustment factor
L = Leaf length (cm)
W = Leaf width (cm)

3.3.1.4 Number of tubers plant^{-1}

The total number of fully developed tubers from the observation plants was recorded and the average number per plant was worked out.

3.3.1.5 Length of tuber

The average length of tuber was worked out by measuring the length of four tubers taken at random from the observation plants and expressed in cm.

3.3.1.6 Girth of tuber

The tubers taken for recording the length were used for taking the girth. Girth was recorded at three places, one at the center and the other two half way between the center and both ends of the tubers. The average was taken as tuber girth and expressed in cm.

3.3.1.7 Tuber yield

Tubers were separated and cleaned to remove the adhering soil, and fresh weight of the tuber from the net plot was recorded. The per hectare yield was worked out and expressed in t ha^{-1}.

3.3.1.8 Top yield

The total weight of the stem and leaves of the plants from the net plot was taken at the time of harvest and converted to t ha^{-1}.

3.3.1.9 Utilization index

This is the ratio of tuber yield to top yield and was worked out from already recorded observations (Obigbesan, 1973).

Fodder grasses

Growth observations of four randomly selected BN hybrid and palisade grass plants in the net plot were recorded prior to each cut. Average of the observations were worked out and presented.

Fodder cowpea

In case of fodder cowpea observations were taken from five randomly selected plants in the net plot at the time of harvest and their average was worked out and presented.

3.3.1.10 Height of the plants

Height of fodder grasses and fodder cowpea were measured from the base of the plant to the tip of the longest leaf. Mean height was worked out and presented in cm.

3.3.1.11 Number of tillers/branches

The number of tillers clump^{-1} were counted in case of fodder grass at the time of harvest and recorded. The total number of branches of fodder cowpea in the selected observation plants of each plot were recorded.

3.3.1.12 Number of leaves plant^{-1}

The number of fully opened leaves retained in the plants was recorded for fodder cowpea at time of harvest.

3.3.1.13 Leaf: stem ratio

Plant samples collected from each harvest were separated into leaf and stem and ratio was computed on dry weight basis.

3.3.1.14 Leaf area index (LAI)

LAI was computed by using the length x width method suggested by Gomez (1972).

$$LAI = \frac{K\,(L \times W) \times \text{Number of leaves plant}^{-1}}{\text{Area occupied by the plant}}$$

where, K= adjustment factor

L=Leaf length (cm)

W= Leaf width (cm)

3.3.1.15 Green fodder yield

Green fodder yield from the net plot area was recorded immediately after harvest, and total green fodder production was worked out.

3.3.1.16 Dry fodder yield

The samples from each cut of grasses and fodder cowpea were first sun dried and then oven dried to a constant weight at 80°C. The dry matter content was computed from each treatment and dry fodder yield was worked out.

3.3.2 Land use efficiency and Biological efficiencies

3.3.2.1 Land equivalent ratio (LER)

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

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

Where A and B are component crops.

3.3.2.2 Aggressivity

The term 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.

$A_{ab} = Y_{ab} / Y_{aa} Z_{ab} - Y_{ba} / Y_{bb} Z_{ba}$ 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’

3.3.2.3 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 cassava
L_B - LER of fodder crops

3.3.2.4 Crop equivalent yield

Crop equivalent yield was worked out by converting the yield of alley crops to the equivalent yield of main crop using the crop equivalent factor (Prasad and Srivastava ,1991).

$$\text{Cassava equivalent yield} = \frac{\text{Yield of fodder crops (t ha}^{-1}\text{) x Market price of unit weight fodder crops}}{\text{Market price of unit weight of cassava}}$$

3.3.3 Quality studies

The oven dried plant samples used for the determination of dry matter content were ground and chemical analysis was carried out for the estimation of nutrients.

Crude protein content was worked out by multiplying the nitrogen content by 6.25 (Simpson et al.,1965).

3.3.4 Uptake studies

Nitrogen, Phosphorus, and potassium content in whole plant on dry weight basis were estimated as per the methods given below and expressed as percentage of nitrogen, phosphorus, and potassium of plant dry matter. From these figures nitrogen, phosphorus and potassium uptake were computed.

Analysis of plant sample

Sl no.	Estimated Character	Method
1	Nitrogen	Alkaline Permanganate method (Subbiah and Asija,1956)
2	Phosphorus	Bray and Kurtz ,1945
3	Potassium	Ammonium acetate method (Jackson,1973)

3.3.5 Analysis of soil before and after experiment

A composite sample of soil was collected from the experimental field from a depth of 10-15 cm from each plot before the commencement of experiment. Similarly soil samples were also collected from each plot at the end of experiment. The samples were dried in shade, sieved by passing through a 2 mm sieve and were analysed for available nitrogen, available phosphorus, and available potassium. The samples were passed through a 0.5 mm sieve and analysed for determining the organic carbon content of the soil.

3.3.6 Economic analysis

The gross return hectare^{-1} for each treatment was worked out. The net returns were calculated by subtracting the cost of cultivation from the total monetary value of yield. Labour requirement for cultivation of cassava was calculated as suggested by Pal et al.(1992).

3.3.7 Statistical Analysis

Statistical Analysis of the data was performed by using the analysis of variance technique proposed by Panse and Sukhatme(1995).

4. RESULTS

An experiment was conducted to study the possibility of raising fodder crops in the alleys of cassava planted in paired rows and to assess the response of the system to AMF application. The data on the various observations are statistically analysed and presented in this chapter.

4.1. PLANT HEIGHT OF CASSAVA AT VARIOUS GROWTH STAGES

The data on the mean plant height of cassava at various growth stages are presented in the Table 4.

Plant height of cassava was not significantly influenced by the treatments at second and fourth months after planting. At six MAP there was significant effect on plant height due to different treatments. Maximum plant height of 106.36 cm was recorded by sole cassava (T_{11}) which was on par with all other treatments except T_1 (cassava +BN hybrid), T_4 (cassava + palisade grass+ AMF) and T_7 (cassava +BN hybrid + fodder cowpea). The lowest plant height of 73.03 was obtained for T_7 (cassava +BN hybrid + fodder cowpea) at 6MAP.

4.2. NUMBER OF LEAVES PER PLANT IN CASSAVA AT VARIOUS GROWTH STAGES

The mean values of number of leaves plant^{-1} of cassava taken at bimonthly intervals are given in the Table 5.

It was seen that there was significant difference between the treatments with regard to the number of leaves at fourth and sixth MAP of cassava. At 4 MAP, T_{11} (sole cassava) recorded the maximum number of leaves of 86.00 which was on par with T_{10} (cassava + palisade grass + fodder cowpea + AMF) and T_5 (cassava + fodder cowpea). T_1 (cassava + BN hybrid) recorded the minimum

Table No.4 Plant height of cassava (cm) at various growth stages

Treatments	2MAP	4MAP	6MAP
T_1	25.91	52.63	73.94
T_2	31.77	62.50	91.26
T_3	29.09	67.21	94.53
T_4	24.67	57.34	81.79
T_5	21.65	57.21	100.06
T_6	23.05	57.22	96.95
T_7	24.05	51.64	73.03
T_8	27.95	63.42	83.00
T_9	24.25	61.72	92.99
T_{10}	27.82	64.96	89.31
T_{11}	27.87	66.92	106.36
T_{12}	-	-	-
T_{13}	-	-	-
T_{14}	-	-	-
SE M$\pm$	2.019	4.701	6.305
CD (0.05)	NS	NS	18.600

`

NS Non significant

number of leaves at 4 MAP (40.66). At 6 MAP also T_{11} (sole cassava) recorded maximum number of leaves (118.33) which was on par with T_3. Minimum number of leaves (47.33) was recorded by T_7 (cassava + BN hybrid + fodder cowpea).

4.3. LEAF AREA INDEX OF CASSAVA AT VARIOUS GROWTH STAGES

Leaf area index of cassava calculated at bi monthly intervals are given in the Table 6.

Treatments had no significant effect on the LAI of cassava at second and sixth month after planting. LAI of cassava significantly differed among the treatments at 4MAP only. T_5 (cassava + fodder cowpea) recorded maximum LAI of 2.01, which was on par with T_{11}, T_3, T_6, T_{10} and T_9. The lowest value (0.66) was recorded by T_1 (cassava + BN hybrid).

4.4 NUMBER OF TUBERS PER PLANT, TUBER LENGTH, TUBER GIRTH OF CASSAVA

The data on mean values of yield attributes like tuber number plant^{-1}, length and girth of tuber are given in the Table 7.

4.4.1 Number of tubers per plant

It was found that the treatments had no significant effect on the yield attributes of cassava. However the highest number of tubers plant^{-1} (5.00) was obtained for T_{10} (cassava + palisade grass + fodder cowpea +AMF) and lowest of 3.00 for T_2, T_4 and T_7.

Table No.5 Number of leaves plant^{-1} in cassava at various growth stages

Treatments	2MAP	4MAP	6MAP
T_1	28.00	40.66	57.66
T_2	31.00	48.00	71.00
T_3	33.66	65.00	92.00
T_4	27.33	56.00	70.00
T_5	20.33	73.66	82.66
T_6	21.33	61.00	80.00
T_7	26.00	42.00	47.33
T_8	34.33	52.00	77.33
T_9	27.66	59.00	84.00
T_{10}	35.00	74.33	86.66
T_{11}	29.33	86.00	118.33
T_{12}	-	-	-
T_{13}	-	-	-
T_{14}	-	-	-
SE M$\pm$	3.414	7.007	10.618
CD(0.05)	NS	20.672	31.325

NS Non significant

Table No.6 Leaf area index of cassava at various growth stages

Treatments	2MAP	4MAP	6MAP
T_1	0.60	0.66	0.89
T_2	0.63	1.09	1.06
T_3	1.02	1.82	1.66
T_4	0.49	1.06	0.90
T_5	0.35	2.01	1.38
T_6	0.22	1.76	1.49
T_7	0.48	0.84	0.57
T_8	0.78	0.98	1.48
T_9	0.53	1.34	1.20
T_{10}	0.61	1.37	1.24
T_{11}	0.50	1.99	1.84
T_{12}	-	-	-
T_{13}	-	-	-
T_{14}	-	-	-
SE M$\pm$	0.151	0.296	0.243
CD(0.05)	NS	0.874	NS

NS Non significant

Table No.7 Number of tubers plant^{-1}, tuber length (cm), tuber girth (cm) of cassava

Treatments	Number of tubers	Tuber length (cm)	Tuber girth (cm)
T_1	3.33	21.86	13.95
T_2	3.00	20.75	15.86
T_3	4.33	26.00	13.57
T_4	3.00	24.07	12.31
T_5	4.66	25.69	14.58
T_6	4.66	26.07	14.06
T_7	3.00	25.84	13.48
T_8	3.33	25.14	13.22
T_9	3.66	26.73	13.68
T_{10}	5.00	23.52	14.17
T_{11}	4.66	31.40	14.47
T_{12}	-	-	-
T_{13}	-	-	-
T_{14}	-	-	-
SE M$\pm$	0.783	3.262	0.836
CD(0.05)	NS	NS	NS

NS Non significant

4.4.2 Tuber length

Treatment T_{11} (sole cassava) produced the longest tubers of 31.40 cm followed by T_9 (26.73 cm) and T_2 (cassava + BN hybrid + AMF) recorded the minimum length of 20.75 cm.

4.4.3 Tuber girth

Highest tuber girth of 15.86 cm was recorded by T_2 (cassava + BN hybrid + AMF) and T_4 (cassava + palisade grass + AMF) recorded the lowest tuber girth of 12.31 cm.

4.5 TUBER YIELD, TOP YIELD AND UTILIZATION INDEX OF CASSAVA.

Mean values of tuber yield (t ha^{-1}), top yield (t ha^{-1}), and utilization index are presented in Table 8.

4.5.1 Tuber yield

The results revealed that tuber yield was significantly influenced by the treatments. T_{11} (sole cassava) recorded significantly higher tuber yield of 22.95 t ha^{-1}. The alley crop combinations of T_6 (16.00 t ha^{-1}), T_9 (12.88 t ha^{-1}), T_{10} (12.10), T_5 (12.02), T_3 (9.40) and T_7 (8.66) were on par with respect to tuber yield of cassava. Lowest yield of 6.13 t ha^{-1} was recorded for T_4 (cassava +palisade grass +AMF).

4.5.2 Top yield

There was significant difference among the treatments for top yield. The highest top yield was recorded by T_{11} (sole cassava) (4.76 t ha^{-1}) which was

Table No.8 Tuber yield (t ha^{-1}), top yield (t ha^{-1}) and utilization index of cassava

Treatments	Tuber yield (t ha^{-1})	Top yield (t ha^{-1})	Utilization index
T_1	6.34	2.92	2.04
T_2	8.39	2.59	3.42
T_3	9.40	3.86	2.80
T_4	6.13	2.76	2.79
T_5	12.02	2.55	4.81
T_6	16.00	3.97	4.29
T_7	8.66	1.55	6.02
T_8	7.49	1.65	5.26
T_9	12.88	2.02	6.38
T_{10}	12.10	2.62	4.77
T_{11}	22.95	4.76	4.83
T_{12}	-	-	-
T_{13}	-	-	-
T_{14}	-	-	-
SE M$\pm$	2.497	0.647	1.254
CD (0.05)	7.367	1.909	NS

NS Non significant

comparable to that of T_6 (3.97), T_3 (3.86) and T_1 (2.92). The lowest top yield of 1.55 t ha^{-1} was recorded in T_7 (cassava + BN hybrid + fodder cowpea).

4.5.3 Utilization index

There was no significant variation between the treatments for utilization index. Highest utilization index of 6.38 was obtained for T_9 (cassava + palisade grass + fodder cowpea) and the lowest value of 2.04 was recorded for T_1 (cassava +BN hybrid).

4.6 PLANT HEIGHT, NUMBER OF TILLERS PER PLANT, LAI AND L: S RATIO OF FODDER GRASSES

Data on mean values of plant height, number of tillers plant $^{-1}$, LAI and L: S ratio of fodder grasses are given in Table 9.

4.6.1 Plant height

Plant height was significantly influenced by the treatments in the first and second harvests. At first harvest, BN hybrid in T_2 (cassava + BN hybrid + AMF) recorded a maximum plant height of 160.67 cm which was on par with T_8 (cassava + BN hybrid + fodder cowpea + AMF) and T_{12} (sole BN hybrid). In the second harvest, T_8 (cassava + BN hybrid + fodder cowpea + AMF) recorded the maximum plant height of 167.38 cm on par with T_7 (cassava + BN hybrid + fodder cowpea) and T_2 (cassava + BN hybrid + AMF). Lowest height at first (77.25 cm) and second harvest (78.42cm) was recorded by T_{13} (sole palisade grass).

Table No.9 Plant height (cm), number of tillers plant $^{-1}$, LAI and L: S ratio of fodder grasses

Treatments	Plant height (cm)		Number of tillers		LAI		L:S ratio	
	1st harvest	2nd harvest	1st Harvest	2nd harvest	1st harvest	2nd harvest	1st harvest	2nd harvest
T_1	133.00	133.75	10.00	16.00	2.47	2.93	5.32	5.67
T_2	160.67	145.71	14.66	19.33	4.14	2.73	4.69	6.67
T_3	98.67	132.81	53.33	64.33	4.50	4.36	3.02	2.37
T_4	87.42	103.28	45.00	62.00	3.36	2.98	2.96	2.27
T_5	-	-	-	-	-	-	-	-
T_6	-	-	-	-	-	-	-	-
T_7	123.73	161.46	11.00	18.00	4.97	3.88	6.36	6.60
T_8	159.58	167.38	14.00	21.66	3.74	4.79	3.65	5.00
T_9	78.00	111.99	51.66	74.33	4.39	4.45	3.23	2.13
T_{10}	92.33	114.08	54.33	64.66	4.37	4.57	3.74	2.08
T_{11}	-	-	-	-	-	-	-	-
T_{12}	153.48	121.46	14.00	26.66	4.81	3.26	5.36	5.33
T_{13}	77.25	78.42	63.33	74.66	4.29	2.72	2.05	2.47
T_{14}	-	-	-	-	-	-	-	-
SE M$\pm$	8.259	8.406	9.047	8.790	0.954	0.999	0.678	1.103
CD (0.05)	24.541	24.978	26.881	26.120	NS	NS	2.015	3.277

NS Non significant

4.6.2 Number of tillers per plant

Significant difference in number of tillers among the treatments was observed in the both harvests. In both harvests maximum number of tillers was produced by T_{13} (sole palisade grass) with 63.33 in first and 74.66 in second harvest which was on par with T_{10}, T_3, T_9 and T_4.

4.6.3 LAI

LAI of fodder grasses did not show any significant difference between the treatments in both harvests. At first harvest BN hybrid of T_7 (cassava + BN hybrid + fodder cowpea) recorded maximum LAI of 4.97 and T_1 (cassava + BN hybrid) recorded the minimum LAI of 2.47. At second harvest T_8 (cassava + BN Hybrid + fodder cowpea + AMF) and T_{13} (sole palisade grass) recorded the maximum and minimum values of 4.79 and 2.72 respectively.

4.6.4 L: S ratio

There was significant effect on L: S ratio of fodder grasses due to treatments in both harvests. L: S ratio was higher for BN hybrid compared to palisade grass.

BN hybrid of T_7 (cassava + BN hybrid + fodder cowpea) recorded the highest L: S ratio of 6.36 which was on par with T_{12}, T_1 and T_2. Lowest L: S ratio of 2.05 was recorded by T_{13} (sole palisade grass). During the second harvest T_2 (cassava + BN hybrid +AMF) registered highest L: S ratio of 6.67 which was on par withT_7, T_1, T_{12} and T_8.

4.7 GREEN FODDER YIELD AND DRY FODDER YIELD OF FODDER GRASSES

The green fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) of fodder grasses are furnished in Table 10.

4.7. 1 Green fodder yield

Yield data showed that treatments had significant influence on green fodder yield at first harvest. T_{12} (sole BN hybrid) produced maximum green fodder yield of 20.54 t ha^{-1} which was on par with T_2 (cassava + BN hybrid + AMF) with 14.35 t ha^{-1}. Green fodder yield was not significantly influenced by the treatments in the second harvest. However at second harvest the highest green fodder yield of 14.63 t ha^{-1} was obtained from T_7 (cassava + BN hybrid + fodder cowpea) followed by T_9 (cassava + palisade grass + fodder cowpea) with 14.55 t ha^{-1} of green fodder yield.

The total green fodder yield of two harvests also did not differ significantly. Maximum green fodder yield of 27.22 t ha^{-1} from the total two harvests was obtained for T_{12} (sole BN hybrid) and minimum of 16.69 t ha^{-1} from T_{10} (cassava + palisade grass + fodder cowpea + AMF).

4.7.2 Dry fodder yield.

In case of dry fodder yield all the treatments differed significantly in first and second harvests and in their combined yield also.

At first harvest, T_{13} (sole palisade grass) registered the highest dry fodder yield of 4.00 t ha^{-1} and was on par with T_{12} (sole BN hybrid) with a yield of 3.66 t ha^{-1}. At second harvest, T_9 (cassava + palisade grass + fodder cowpea) recorded maximum dry fodder yield of 4.52 t ha^{-1} which was on par with T_3 (3.04 t ha^{-1}).

Table No.10 Green fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) of fodder grasses

Treatments	Green fodder yield (t ha^{-1})			Dry fodder yield (t ha^{-1})		
	1st harvest	2nd harvest	Total	1st harvest	2nd harvest	Total
T_1	11.37	12.90	24.28	1.87	2.52	4.40
T_2	14.35	9.06	23.22	1.98	1.80	3.78
T_3	9.45	9.52	18.98	1.84	3.04	4.88
T_4	7.46	9.88	17.35	1.41	2.72	4.13
T_5	-	-	-	-	-	-
T_6	-	-	-	-	-	-
T_7	9.34	14.63	23.98	1.08	2.60	3.68
T_8	12.01	9.88	21.90	2.12	1.47	3.58
T_9	5.58	14.55	20.14	0.97	4.52	5.49
T_{10}	7.23	9.45	16.69	1.53	1.95	3.47
T_{11}	-	-	-	-	-	-
T_{12}	20.54	8.01	27.22	3.66	1.78	5.44
T_{13}	12.12	9.96	22.34	4.00	2.45	6.45
T_{14}	-	-	-	-	-	-
SE M$\pm$	2.452	1.662	2.483	0.476	0.569	0.624
CD(0.05)	7.287	NS	NS	1.414	1.692	1.855

NS Non significant

Total dry fodder yield from the two harvests also differed significantly between the treatments. Highest total dry fodder yield of 6.45 t ha^{-1} was obtained from T_{13} (sole palisade grass) which was on par with T_9, T_{12} and T_3.

4.8 PLANT HEIGHT, NUMBER OF BRANCHES PER PLANT, NUMBER OF LEAVES PER PLANT, LAI AND L: S RATIO OF FODDER COWPEA.

Growth characters like plant height, number of branches per plant, number of leaves per plant, LAI and L: S ratios of fodder cowpea taken at the time of harvest are given in the Table 11.

4.8.1 Plant height

There was no significant effect of the treatments on plant height of fodder cowpea. T_{14} (sole fodder cowpea) recorded a maximum plant height of 98.70 cm and T_5 (cassava + fodder cowpea) recorded the minimum plant height of 58.87cm.

4.8.2 Number of leaves per plant

Number of leaves of fodder cowpea did not show any significant difference between the treatments. Maximum number of leaves (19.66) was recorded by T_7 (cassava + BN hybrid + fodder cowpea).

4.8.3 Number of branches per plant

No significant effect of treatments was observed on the number of branches T_7 (cassava + BN hybrid + fodder cowpea) and T_9 (cassava + palisade grass + fodder cowpea) produced maximum number of branches of 2.33.

Table No.11 Plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1}, LAI and L: S ratio of fodder cowpea.

Treatments	Plant height	Number of leaves	Number of branches	LAI	L:S ratio
T_1	-	-	-	-	-
T_2	-	-	-	-	-
T_3	-	-	-	-	-
T_4	-	-	-	-	-
T_5	58.87	9.33	0.66	2.05	0.02
T_6	66.49	14.00	1.00	2.99	1.42
T_7	90.38	19.66	2.33	3.96	1.00
T_8	95.24	13.00	2.00	3.83	1.01
T_9	73.87	15.66	2.33	5.36	1.24
T_{10}	67.11	13.33	1.66	4.01	0.94
T_{11}	-	-	-	-	-
T_{12}	-	-	-	-	-
T_{13}	-	-	-	-	-
T_{14}	98.70	12.66	1.33	3.34	1.07
SE M$\pm$	15.599	2.749	0.630	0.671	0.172
CD(0.05)	NS	NS	NS	NS	NS

NS Non significant

4.8.4 LAI

The LAI of fodder cowpea recorded no significant variation due to treatments. T_9 (cassava + palisade grass + fodder cowpea) recorded maximum LAI (5.36).

4.8.5 L: S ratio

The treatments had no significant effect on L: S ratio of fodder cowpea. However T_6 (cassava + fodder cowpea + AMF) recorded maximum L: S ratio of 1.42.

4.9 GREEN FODDER YIELD AND DRY FODDER YIELD OF FODDER COWPEA

The green fodder yield and dry fodder yield of fodder cowpea is given in the Table.12.

4.9.1 Green fodder yield

The cumulative green fodder yield from the two harvests was found to be significantly influenced by treatments. Sole fodder cowpea crop (T_{14}) registered maximum green fodder yield of 13.14 t ha^{-1} which was on par with T_6 (cassava + fodder cowpea + AMF) (10.02 t ha^{-1}). T_7 (cassava +BN hybrid + fodder cowpea) (1.65 t ha^{-1}) recorded the lowest fodder cowpea green fodder yield.

4.9.2 Dry fodder yield

Dry fodder yield of fodder cowpea was significantly influenced by the treatments. T_{14} (sole fodder cowpea) was significantly superior to all other treatments with a dry fodder yield of 2.34 t ha^{-1}.

Table No.12 Green fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) of fodder cowpea

Treatments	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})
T_1	-	-
T_2	-	-
T_3	-	-
T_4	-	-
T_5	8.90	1.55
T_6	10.02	1.40
T_7	1.65	0.29
T_8	1.68	0.33
T_9	2.16	0.65
T_{10}	2.16	0.23
T_{11}	-	-
T_{12}	-	-
T_{13}	-	-
T_{14}	13.14	2.34
SE M$\pm$	1.054	0.171
CD (0.05)	3.248	0.527

4.10 TOTAL GREEN FODDER YIELD AND DRY FODDER YIELD OF THE SYSTEM.

The total green fodder yield and dry fodder yield of the system is given in the Table.13.

The results revealed that there was significant difference in the total green and dry fodder yield of the system among the treatments. Sole BN hybrid (T_{12}) recorded highest total green fodder yield of 27.22 t ha^{-1} on par with T_1, T_2, T_7, T_8, T_9 and T_{13}. Highest total dry fodder yield of 6.45 t ha^{-1} was obtained from T_{13} (sole palisade grass) which was on par with T_9, T_3 and T_{12}.

4.11 QUALITY STUDIES

4.11.1Crude protein content of fodder crops

Mean crude protein content of the fodder crops and crude protein yield are given in the Table 14.

The results revealed that there was no significant difference between the treatments in the crude protein content. T_{12} (sole BN hybrid) recorded the highest crude protein content of 8.37 percent.

Crude protein content of fodder cowpea was also not significantly influenced by the treatments. Highest crude protein content of 20.83 percent was recorded by T_7 (cassava + BN hybrid + fodder cowpea) and lowest of 17.94 percent by T_6 (cassava + fodder cowpea + AMF).

Table No.13 Total green fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) of the system

Treatments	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})
T_1	24.28	4.40
T_2	23.20	3.78
T_3	18.98	4.88
T_4	17.35	4.13
T_5	8.90	1.55
T_6	10.02	1.40
T_7	25.62	3.96
T_8	23.59	3.91
T_9	22.30	6.14
T_{10}	18.85	3.70
T_{11}	-	-
T_{12}	27.22	5.44
T_{13}	22.34	6.45
T_{14}	13.14	2.34
SE M$\pm$	2.450	0.593
CD (0.05)	7.152	1.451

Table No.14 Crude protein content (%) and crude protein yield (t ha^{-1}) of fodder crops

Treatments	Crude protein (%)		Crude protein yield (t ha^{-1})
	Fodder grasses	Fodder cowpea	
T_1	7.32	_	0.32
T_2	6.05	_	0.23
T_3	6.77	_	0.34
T_4	7.46	_	0.29
T_5	_	18.75	0.29
T_6	_	17.94	0.25
T_7	6.87	20.83	0.31
T_8	6.16	20.25	0.29
T_9	8.15	19.74	0.59
T_{10}	7.70	20.81	0.29
T_{11}	-	-	-
T_{12}	8.37	_	0.46
T_{13}	7.45	_	0.48
T_{14}	_	19.95	0.46
SE M$\pm$	0.715	1.170	0.046
CD(0.05)	NS	NS	0.136

NS Non significant

4.11.2 Crude protein yield of the system

The treatment cassava + palisade grass + fodder cowpea produced significantly higher crude protein yield (0.59 t ha^{-1}) on par with T_{12}, T_{13} and T_{14}.

4.12 NUTRIENT UPTAKE STUDIES

4.12.1 Nutrient uptake by cassava

The data on mean values of uptake of nutrients by cassava is presented in the Table 15.

4.12.1.1 *Uptake of Nitrogen*

Uptake of nitrogen by cassava was not significantly influenced by the treatments. T_5 (cassava + fodder cowpea) registered the maximum uptake of 51.39 (kg ha^{-1}**)** and T_7 (cassava + BN hybrid + fodder cowpea) the minimum uptake of 23.21 kg ha^{-1}.

4.12.1.2 *Uptake of phosphorus*

There was no significant difference in the uptake of phosphorus due to treatments by cassava. Maximum uptake was by T_3 (4.24 kg ha^{-1}) and minimum by T_1 (1.79 kg ha^{-1}).

4.12.1.3 *Uptake of potassium*

Potassium uptake was not significantly influenced by the treatments. T_5 (19.55 kg ha^{-1}) recorded the maximum uptake and T_8 (5.57 kg ha^{-1}) the minimum.

Table No.15 Nutrient uptake by cassava (kg ha^{-1})

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	40.45	1.79	9.46
T_2	41.35	4.03	9.45
T_3	41.40	4.24	5.98
T_4	39.13	2.89	11.93
T_5	51.39	2.79	19.55
T_6	43.16	2.39	13.25
T_7	23.21	2.78	6.58
T_8	25.55	2.19	5.57
T_9	33.78	2.63	7.11
T_{10}	40.08	2.80	6.62
T_{11}	39.95	2.76	9.33
T_{12}	-	-	-
T_{13}	-	-	-
T_{14}	-	-	-
SE M$\pm$	6.488	0.643	3.048
CD(0.05)	NS	NS	NS

NS Non significant

4.12.2 Nutrient uptake by fodder grasses

The data on mean values of uptake of nutrients by the fodder grasses are given in the Table 16.

4.12.2.1 *Uptake of Nitrogen*

T_{12} (sole BN hybrid) registered the maximum uptake of 83.14 kg ha^{-1} which was on par with that of T_{13} (sole palisade grass).

4.12.2.2 *Uptake of phosphorus*

No significant difference was observed between the treatments in case of phosphorus uptake. Highest uptake of phosphorus was recorded by T_{12} (sole BN hybrid) (59.64).

4.12.2.3 *Uptake of potassium*

Potassium uptake was also not significantly influenced by the treatments. T_{12} (sole BN hybrid) recorded highest uptake of 144.13 kg $ha^{-1.}$

4.12.3 Nutrient uptake by fodder cowpea

Nutrient uptake by fodder cowpea is given in the Table 17.

4.12.3.1 *Uptake of Nitrogen*

From the results it was observed that nitrogen uptake of fodder cowpea was significantly influenced by the treatments. T_{14} (sole fodder cowpea) registered the maximum uptake of (121.31kg ha^{-1}).

Table No.16 Nutrient uptake by fodder grasses (kg ha^{-1})

Treatments	Nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
T_1	31.48	33.37	60.91
T_2	43.84	43.96	72.87
T_3	49.18	27.75	93.27
T_4	43.01	23.92	129.50
T_5	-	-	-
T_6	-	-	-
T_7	46.83	32.42	161.66
T_8	47.62	45.58	120.81
T_9	52.23	19.30	84.19
T_{10}	53.51	27.65	113.63
T_{11}	-	-	-
T_{12}	83.14	59.64	144.13
T_{13}	75.20	30.63	107.56
T_{14}	-	-	-
SE M$\pm$	10.597	10.239	30.049
CD (0.05)	24.704	NS	NS

NS Non significant

Table No.17 Nutrient uptake by fodder cowpea (kg ha^{-1})

Treatments	Nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
T_1	-	-	-
T_2	-	-	-
T_3	-	-	-
T_4	-	-	-
T_5	39.84	2.56	11.43
T_6	24.49	2.90	14.03
T_7	51.72	0.56	2.14
T_8	48.40	0.69	3.28
T_9	44.66	0.92	3.33
T_{10}	37.86	0.77	1.66
T_{11}	-	-	-
T_{12}	-	-	-
T_{13}	-	-	-
T_{14}	121.31	6.37	45.34
SE M$\pm$	12.814	0.622	3.877
CD (0.05)	39.487	1.918	11.949

NS Non significant

4.12.3.2 *Uptake of phosphorus*

Phosphorus uptake by fodder cowpea was significantly influenced by the treatments. T_{14} (sole fodder cowpea) was found to be significantly superior to all other treatments in the uptake of phosphorus (6.37 kg ha^{-1}). Higher P uptake of due to AMF application was recorded by T_6 (cassava + fodder cowpea + AMF) compared to T_5 (cassava + fodder cowpea).

4.12.3.3 *Uptake of potassium*

Significantly higher potassium uptake of 45.34 kg ha^{-1} was also seen in T_{14} (sole fodder cowpea).

4.12.4 Total uptake of nutrients

Total nutrient uptake of the system is given in the Table 18.

Significant difference was seen among the treatments with respect to total uptake of nutrients.

4.12.4.1 *Uptake of nitrogen*

T_{10} (cassava + palisade grass + fodder cowpea + AMF) registered significantly higher nitrogen uptake of 131.46 kg ha^{-1} and was on par with T_{14}, T_9, T_8, and T_7. The minimum uptake was registered by T_{11} (sole cassava).

4.12.4.2 *Uptake of phosphorus*

Sole crop of BN hybrid recorded maximum uptake of 59.64 kg ha^{-1} on par with T_1, T_2, T_7 and T_8. The minimum uptake was in T_{11} (sole cassava).

Table No.18 Total nutrient uptake (kg ha^{-1})

Treatments	Total Nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
T_1	71.93	35.16	70.36
T_2	85.19	47.98	82.32
T_3	90.58	31.99	99.25
T_4	82.14	26.82	141.45
T_5	91.23	5.35	30.98
T_6	72.65	5.28	27.28
T_7	121.76	35.76	170.39
T_8	121.57	48.46	129.72
T_9	130.67	22.86	94.64
T_{10}	131.46	31.21	121.91
T_{11}	39.95	2.76	9.33
T_{12}	83.14	59.64	144.13
T_{13}	75.20	30.63	107.56
T_{14}	121.31	6.37	45.34
SE M±	11.599	8.529	25.89
CD (0.05)	33.727	24.799	75.30

4.12.4.3 *Uptake of potassium*

The treatment T_7 (cassava + BN hybrid + fodder cowpea) recorded maximum uptake of 170.39 kg ha^{-1} and was on par with T_3, T_4, T_8, T_{10}, T_{12} and T_{13}.

4.13 SOIL ANALYSIS AFTER THE EXPERIMENT

The mean values of data of the soil analysis after the experiment are presented in the Table 19.

4.13.1 Available nitrogen in the soil

The treatments had no significant effect on the available nitrogen in soil. Maximum content of available nitrogen of 393.42 kg ha^{-1} was recorded by T_{14} (sole fodder cowpea) and the minimum value by T_7 (296.64 kg ha^{-1}). Compared to treatments without AMF application, available nitrogen content was high in AMF applied treatments.

4.13.2 Available phosphorus in the soil

Available phosphorus in soil did not have any significant effect due to different treatments. However T_3 (cassava + palisade grass) recorded the highest content of 82.69 kg ha^{-1} and lowest value by T_8 (38.73 kg ha^{-1}).

4.13.3 Available potassium in the soil

There was no significant difference in available potassium content of the soil between the different treatments after the experiment. T_6 (cassava + fodder cowpea + AMF) recorded the highest potassium content of 131.63 kg ha^{-1}. The lowest value (47.67) was recorded by T_{12}.

Table No.19 Soil nutrient status after the experiment (kg ha^{-1})

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Organic carbon (%)
T_1	321.96	69.75	55.07	0.74
T_2	380.50	66.57	105.30	0.94
T_3	342.85	82.69	81.67	0.94
T_4	357.51	42.83	73.70	0.81
T_5	380.50	66.25	105.23	0.88
T_6	385.14	58.34	131.63	0.88
T_7	296.64	59.80	63.07	0.98
T_8	344.96	38.73	61.23	0.87
T_9	321.96	55.40	86.17	0.93
T_{10}	334.51	60.14	114.14	0.86
T_{11}	334.39	56.12	102.68	0.88
T_{12}	355.41	74.21	47.67	0.80
T_{13}	330.14	50.61	49.13	0.65
T_{14}	393.42	63.70	65.80	0.85
SE M$\pm$	25.072	8.060	22.372	0.046
CD (0.05)	NS	NS	NS	0.136

NS Non significant

4.13.4 Organic carbon content in the soil

Organic carbon content of the soil was significantly influenced by the treatments. T_7 (cassava + BN hybrid + fodder cowpea) recorded highest organic carbon content of 0.98 percent which was on par with all other treatments except T_1, T_{13}, T_4 and T_{12}.

4.14. LAND USE EFFICIENCY AND BIOLOGICAL EFFICIENCY

Land use efficiency and biological efficiencies of the system was worked out and presented in Tables 20 and 21.

4.14.1 Land equivalent ratio and land equivalent coefficient

The total LER of the alley cropping system was not significantly influenced by the treatments. In case of individual crops LER of fodder cowpea alone varied significantly among the treatments and T_6 (cassava + fodder cowpea + AMF) registered a maximum LER of 0.78 on par with T_5 (cassava + fodder cowpea). The highest LER of (1.70) of the system was recorded in T_9 (cassava + palisade grass + fodder cowpea) followed by T_{10} (cassava + palisade grass + fodder cowpea +AMF) and T_6 (cassava +fodder cowpea + AMF) with LER of 1.47. Land equivalent coefficient was also found to be not significantly influenced by the treatments. However T_6 (cassava + fodder cowpea + AMF) registered the maximum LEC of 0.56. Lowest LEC value of 0.07 was recorded for T_{10} (cassava + palisade grass + fodder cowpea + AMF).

Table No.20 Land equivalent ratio and land equivalent coefficient

Treatments	Land equivalent ratio			Land equivalent ratio of the system	Land equivalent coefficient
	Cassava	Fodder grass	Fodder cowpea		
T_1	0.45	0.91	_	1.18	0.22
T_2	0.37	0.84	_	1.22	0.31
T_3	0.43	0.88	_	1.30	0.35
T_4	0.27	0.80	_	1.00	0.20
T_5	0.53	_	0.69	1.20	0.34
T_6	0.69	_	0.78	1.47	0.56
T_7	0.37	0.87	0.13	1.30	0.39
T_8	0.34	0.73	0.13	1.19	0.24
T_9	0.58	0.95	0.17	1.70	0.09
T_{10}	0.59	0.77	0.15	1.47	0.07
T_{11}	1.00	1.00	1.00	1.00	1.00
T_{12}	1.00	1.00	1.00	1.00	1.00
T_{13}	1.00	1.00	1.00	1.00	1.00
T_{14}	1.00	1.00	1.00	1.00	1.00
SE M$\pm$	0.110	0.127	0.082	0.147	0.196
CD (0.05)	NS	NS	0.321	NS	NS

NS Non significant

Table No.21 Aggressivity and cassava equivalent yield (kg ha^{-1})

Treatments	Aggressivity		Cassava equivalent yield (t ha^{-1})
	Cassava	Fodder crops	
T_1	-0.64	0.64	13.62
T_2	-0.47	0.47	15.38
T_3	-0.45	0.45	15.09
T_4	-0.48	0.48	11.33
T_5	-0.29	0.29	15.57
T_6	-0.25	0.25	20.01
T_7	-0.58	0.58	16.51
T_8	-0.54	0.54	14.73
T_9	-0.52	0.52	19.78
T_{10}	-0.35	0.35	17.97
T_{11}	-	-	22.95
T_{12}	-	-	8.16
T_{13}	-	-	6.70
T_{14}	-	-	5.24
SE M$\pm$	0.196	0.196	2.168
CD(0.05)	NS	NS	6.304

NS Non significant

4.14.2 Aggressivity and cassava equivalent yield

The results indicate that there was no significant difference in the aggressivity of cassava and fodder crops between the treatments.

Cassava equivalent yield showed significant difference between the treatments. Highest cassava equivalent yield of 22.95 t ha^{-1} was recorded by T_{11} (sole cassava) which was on par with T_6 (cassava + fodder cowpea + AMF), T_9 (cassava + palisade grass + fodder cowpea) and T_{10} (cassava + palisade grass + fodder cowpea + AMF) with cassava equivalent yield of 20.01, 19.78 and 17.97 t ha^{-1} respectively and lowest cassava equivalent yield of 5.25 t ha^{-1} was recorded by T_{14} (sole fodder cowpea).

4.15. ECONOMICS OF ALLEY CROPPING IN CASSAVA.

The data on economics of cultivation is given in Table.22.

All the treatments were comparable with respect to net income. The highest net income of Rs. 64507 was obtained from T_{11} (sole crop of cassava) followed by T_9 (cassava + palisade grass + fodder cowpea) with a net income of Rs.39100. Significantly higher B: C ratio of 2.28 was obtained for sole cassava (T_{11}), followed by T_9 (cassava +palisade grass +AMF) with a B: C ratio of 1.52. The cassava equivalent income of sole cassava (T_{11}) was the highest (Rs.114766 ha^{-1}) and was on par with that of T_6 (Rs.100033 ha^{-1}), T_9 (Rs. 98936 ha^{-1}) and T_{10} (Rs. 89855 ha^{-1}).

4.16. EFFECT OF ALLEY CROPS AND AMF ON BIOLOGICAL, ECONOMIC AND LAND USE EFFICIENCY OF THE SYSTEM

In order to find out the effect of alley crops and AMF on biological, economic and land use efficiency of the system, the data on cassava equivalent

Table No 22 Economics of alley cropping in cassava

Treatments	Cost of production (Rs ha^{-1})	Anticipated gross returns for one year (Rs ha^{-1})	Net income (Rs ha^{-1})	B:C ratio	Cassava equivalent income (Rs ha^{-1})
T_1	81739	86320	4581	1.06	68108
T_2	87555	94436	6880	1.08	76946
T_3	72760	89729	16968	1.23	75491
T_4	78576	69679	-8896	0.89	56670
T_5	63335	77883	14547	1.23	77883
T_6	71254	100033	28779	1.40	100033
T_7	83920	100540	16620	1.20	82558
T_8	90644	98099	-545	0.99	73671
T_9	74941	114041	39100	1.52	98936
T_{10}	81665	102372	20707	1.25	89855
T_{11}	50243	114730	64507	2.28	114766
T_{12}	47010	61244	14235	1.30	40830
T_{13}	33608	50272	16664	1.49	33515
T_{14}	26185	26273	88	1.00	26426
SE M$\pm$	-	-	12623	0.155	10846
CD(0.05)	-	-	NS	0.451	31536

NS Non significant

Table No.23 Effect of alley crops and AMF on biological, economic and land use efficiency of the system

Treatments	Cassava equivalent yield (t ha^{-1})	Cassava equivalent income (Rs ha^{-1})	LER
BN	14.50	72527	1.20
PG	13.22	66080	1.15
FC	17.79	88958	1.33
BN+FC	15.62	78115	1.25
PG+FC	18.88	94395	1.58
SE M±	1.534	7669	0.090
CD(0.05)	NS	NS	0.262
A_0	16.12	80595	1.34
A_1	15.89	79435	1.27
SE M±	0.970	4850	4850
CD(0.05)	NS	NS	NS
BN + A_0	13.62	68108	1.18
	15.39	76946	1.22
BN + A_1	15.10	75491	1.30
PG+ A_0	11.33	56670	1.00
PG++ A_1	15.58	77883	1.20
FC+ A_0	20.01	100033	1.47
FC++ A_1	16.51	82558	1.30
BN+FC+ A_0	14.73	73671	1.19
BN+FC++ A_1	19.79	98936	1.70
PG+FC+ A_0	17.97	89855	1.47
PG+FC++ A_1	2.169	10846	0.127
SE M±	NS	NS	NS
CD(0.05)			
Sole cassava	22.95	114766	1.00
Sole BN hybrid	8.16	40830	1.00
Sole palisade grass	6.70	33515	1.00
Sole fodder cowpea	5.24	26246	1.00

NS Non significant

Table No.24 Biological, economic and land use efficiency of the system

Treatments	Total productivity and quality		Economics of the system		LER
	Cassava equivalent yield (t ha^{-1})	Crude protein yield (t ha^{-1})	Cassava equivalent income (Rs ha^{-1})	B:C ratio	
T_1	13.62	0.32	68108	1.06	1.18
T_2	15.38	0.23	76946	1.08	1.22
T_3	15.09	0.34	75491	1.23	1.30
T_4	11.33	0.29	56670	0.89	1.00
T_5	15.57	0.29	77883	1.23	1.20
T_6	20.01	0.25	100033	1.40	1.47
T_7	16.51	0.31	82558	1.20	1.30
T_8	14.73	0.29	73671	0.99	1.19
T_9	19.78	0.59	98936	1.52	1.70
T_{10}	17.97	0.29	89855	1.25	1.47
T_{11}	22.95	-	114766	2.28	1.00
T_{12}	8.16	0.46	40830	1.30	1.00
T_{13}	6.70	0.48	33515	1.49	1.00
T_{14}	5.24	0.46	26426	1.00	1.00
SE M$\pm$	2.168	0.046	10846	0.155	0.147
CD(0.05)	6.304	0.136	31536	0.451	NS

NS Non significant

yield and cassava equivalent income and LER were analysed in factorial design, with five alley crops, BN hybrid (BN), palisade grass (PG), fodder cowpea (FC), BN hybrid + fodder cowpea (BN + FC), palisade grass + fodder cowpea (PG + FC), and two levels of AMF (A_0 – without AMF and A_1 – with AMF). The result is presented in the Table.23.

The results indicated that there was no significant difference between the treatments with respect to the alley crops and also due to the application of AMF and their interaction on cassava equivalent yield and cassava equivalent income. Alley cropping palisade grass + fodder cowpea and fodder cowpea alone resulted in significantly higher LER of 1.58 and 1.33 respectively. The application of AMF did not influence the LER of the system.

4.17 BIOLOGICAL, ECONOMIC AND LAND USE EFFICIENCY OF THE SYSTEM

The data on total biological productivity, quality, economics and land use efficiency of the system are presented in Table.24.

The cassava equivalent yield of sole cassava was the highest (22.95 t ha^{-1}) and was on par with T_9 (cassava + palisade grass + fodder cowpea). The performance of T_9 was also significantly superior in the production of crude protein yield (0.59 t ha^{-1}). The cassava equivalent income of sole cassava (T_{11}) was the highest (Rs.114766 ha^{-1}) and was on par with that of T_6 (Rs.100033 ha^{-1}), T_9 (Rs.98936 ha^{-1}) and T_{10} (Rs.89855 ha^{-1}). Significantly higher B: C ratio of 2.28 was obtained for sole cassava (T_{11}), followed by T_9 (cassava +palisade grass +AMF) with a B: C ratio of 1.52. The highest LER of (1.70) of the system was recorded in T_9 (cassava + palisade grass + fodder cowpea).

Discussion

5. DISCUSSION

The present study was conducted to asses the bio and economic suitability of raising fodder crops in the alleys of cassava for food - fodder production and to study the response of the system to AMF application. The results obtained are briefly discussed in this chapter.

5.1 PLANT HEIGHT OF CASSAVA AT VARIOUS GROWTH STAGES

Plant height of cassava was not influenced by the treatments at second and fourth month after planting.

In the initial stages of alley cropping, (2 MAP) the application of required dose of fertilizers to both crops reduced the competition for nutrients and resulted in uniform growth of cassava plants. Similar results were obtained by Anilkumar (1984b) and Biju (1989). After the first harvest of the alley crops on 62 (fodder cowpea) and 83 (fodder grass) days after planting of cassava, increased availability of sunlight for cassava might have stimulated active rapid growth of cassava producing uniform height in all plots. This was in support with the findings of Sheela (1981).

At 6 MAP there was significant influence of treatments on the height of cassava plants. Sole crop of cassava recorded maximum plant height at 6 MAP which was on par with cassava + fodder cowpea. In the sole crop plots since there were no intercrops cassava plants experienced lesser competition for water, nutrients, light etc compared to the intercropped plots, where exist a tight competition. This provided a favourable condition for the rapid growth of cassava resulting in an increase in height which is evident from the data on aggressivity. Similar results were obtained by Prabhakar and Nair (1992). Among the alley crops fodder cowpea plants competed less with cassava plants compared to fodder grasses. This resulted in better growth of cassava plants along with cowpea than with fodder grasses. The data recorded on aggressivity supports this finding. The combinations of cassava involving BN hybrid with and with out fodder legume (T_1 and T_7) resulted in reduction in plant height of cassava at 6 MAP which is supported by the observation that BN hybrid is more aggressive among the grasses.

5.2 NUMBER OF LEAVES PER PLANT IN CASSAVA AT VARIOUS GROWTH STAGES

Leaf production in cassava was not significantly influenced by the treatments at two months after planting. At 2 MAP as stated earlier the alley crops had no effect on the growth of cassava and created uniform growth conditions in all treatments. Thus no significant difference was observed in number of leaves produced plant^{-1}. Biju (1989) also reported similar results.

Significant influence was seen due to the treatments on the leaf production in cassava at fourth and sixth MAP. At 4 MAP sole crop of cassava produced maximum number of leaves and was on par with T_{10} (cassava + palisade grass + fodder cowpea + AMF) and T_5 (cassava + fodder cowpea). Higher leaf production in sole cassava is due to the favourable environmental conditions in the sole crop plots under competition free environment. In cassava + fodder cowpea plots nitrogen supplied by the fodder cowpea may have increased the leaf production. Bridgit (1985) obtained similar results, when cassava was intercropped with groundnut. In the plots where cassava alley cropped with palisade grass and fodder cowpea with AMF, along with symbiotic nitrogen fixation by fodder cowpea, inoculation with AM fungi might have increased the nutrient availability in the plots there by favouring better plant growth through higher leaf production similar to that of sole crop plots. This is in accordance with the findings of Narayanan (1991). Alley crop combinations of cassava with BN hybrid either with or without fodder cowpea and AMF resulted in reduction in leaf number plant^{-1} which may be due to the higher aggressivity of BN hybrid.

At 6 MAP also maximum leaf production was recorded by sole crop of cassava which was comparable with T_3 (cassava + palisade grass). Increase in plant height, in sole crop of cassava, due to the lack of competition by the alley crops might have contributed to more number of leaves plant^{-1} in sole cassava. This is in support with the findings of Prabhakar and Nair (1992). The plant height of palisade grass is lesser compared to BN hybrid which would have resulted in better availability of solar radiation in cassava resulting in higher leaf number in T_3 (cassava + palisade grass).

5.3 LEAF AREA INDEX OF CASSAVA AT VARIOUS GROWTH STAGES

The results revealed that there was significant effect of treatments on LAI of cassava at 4 MAP. Non significance in number of leaves might have resulted in non significance of LAI in 2 MAP.

At 4 MAP, highest LAI of 2.01 was recorded by the treatment cassava + fodder cowpea (T_5) which was comparable to the sole cassava (T_{11}), cassava + fodder cowpea+ AMF (T_6), cassava + palisade grass (T_3), cassava + palisade grass + fodder cowpea (T_9) and cassava + palisade grass + fodder cowpea + AMF (T_{10}). This may be due to the higher leaf production in these treatments at this stage. LAI of cassava depends on the number of leaves produced, individual leaf area, its longevity and number of branches (Alves ,2003; Ghosh et al.,1988).

Alley crop combinations of palisade grass, fodder cowpea or their combinations were responsible for significantly higher LAI in cassava, which indicates the suitability of these crops in alley cropping in cassava. The lowest value of LAI (0.66) was recorded by cassava + BN hybrid, where the total number of leaves produced plant^{-1} (40.66) was lowest. Similar findings were also reported by Biju (1989).

At 6 MAP even though the number of leaves produced was significantly different the non significance in the LAI may be due to influence of other factors affecting LAI like individual leaf area, leaf longevity etc. The application of AMF had no influence on LAI of cassava.

5.4 NUMBER OF TUBERS PER PLANT, TUBER LENGTH AND TUBER GIRTH OF CASSAVA

5.4.1 Number of tubers per plant

Number of tubers produced by cassava was not influenced by alley cropping. The number of tubers produced in the sole cassava was comparable to that in alley cropped cassava. After the first harvest of the alley crops on 62 (fodder cowpea) and 83 (fodder grass) days after planting of cassava, increased availability of sunlight for cassava resulted in active growth of cassava producing uniform height and LAI in all treatments. The application of AMF had no influence on number of tubers in cassava.

5.4.2 Tuber length

Tuber length of cassava failed to show any significant difference between the treatments. Length of the tuber was maximum in sole crop of cassava followed by cassava + palisade grass + fodder cowpea and cassava + fodder cowpea + AMF. In cassava + fodder cowpea plots loose soil conditions produced by up rooting of fodder cowpea may have helped the cassava to penetrate easily through the soil resulting in the production of tubers almost similar in length of sole cassava. This is in support with the findings of Sheela (1981); Anilkumar (1984b) and Biju (1989). With palisade grass crop combinations due to less aggressive nature of the grass, the tuber length of cassava was higher though not significant. The application of AMF had no influence on tuber length in cassava.

5.4.3 Tuber girth

Alley cropping had no significant influence on the tuber girth of cassava. Anilkumar (1984b); Sheela (1981) and Anilkumar et al., 1990 had also found no significant effect on tuber girth due to intercropping in cassava. However cassava + BN hybrid + AMF which showed lower value for length of tuber recorded highest value of tuber girth. This may be due to allocation of more assimilates in building the girth of the tuber which reduced their availability in increasing the length. The application of AMF had no influence on tuber girth in cassava.

5.5 TUBER YIELD, TOP YIELD AND UTILIZATION INDEX OF CASSAVA.

5.5.1 Tuber yield

The results of the study revealed that there was significant difference in the tuber yield between treatments (Fig.4). From the yield data, it was observed that sole crop of cassava registered highest tuber yield followed by cassava + fodder cowpea + AMF. Increased yield in pure crop of cassava compared to intercropped cassava was also reported by Anilkumar (1984b); Karnik et al. (1993); Udoh and Ndaeyo (2000) and Amanullah et al., 2006a. Highest tuber yield in sole cassava may be attributed to the production of more number of tubers and increased length of tubers in sole cassava. This may be due to absence of competition for better utilization of water, nutrients, light etc in sole crop plots. This is in conformity with the results of Anilkumar (1984b). Also at the time of harvest, sole cassava registered maximum height, number of leaves and LAI, resulting in increased photosynthesis and accumulation of more photosynthates in the tubers.

Beneficial effect of fodder cowpea and AMF had resulted in better tuber yield of cassava in cassava + fodder cowpea + AMF treatment. This may be due to the higher uptake of nutrients by cassava when grown along with fodder cowpea.

Among the fodder grasses, cassava grown along with BN hybrid produced comparatively low yield. There was 62.23 percent reduction in tuber yield of cassava due to BN hybrid + fodder cowpea alley cropping. This may be due to high shading effect by the vigorous growth of the grass which is evident from the lesser number of tubers shorter in length compared to that produced in cassava + palisade grass plots. When palisade grass + fodder cowpea was alley cropped in cassava the tuber yield reduction recorded was only 43.90 percent. Hence palisade grass is a better fodder grass component for alley cropping in cassava compared to BN hybrid.

The application of AMF had no influence on the tuber yield of cassava. Sivaprasad et al. (1989) has reported an yield reduction in tuber yield of sweet potato when inoculated by *Glomus fasciculatum.*

5.5.2 Top yield

Sole cassava recorded highest top yield on par with T_6, T_1 and T_3. Highest plant height and number of leaves in sole cassava attributed to the increase in top yield in sole crop plots. The increased availability of sufficient quantity of nitrogen released through out the growth period of cassava may have encouraged good vegetative growth in plants and canopy build up resulting in high top yield in cassava +fodder cowpea plots. Sheela (1981) also reported similar findings.

Cassava along with fodder grasses also exhibited good vegetative growth of plants which may be due to distribution of more photo assimilates to the stem and leaves which is evident from their low tuber yield compared to other treatments.

The application of AMF had no influence on the top yield of cassava as reported by Sivaprasad et al. (1989).

5.5.3 Utilization index

The results showed that there is no significant difference between treatments regarding the utilization index (Fig.5). This means that cassava plants in different treatments have similar capacity in translocating carbohydrate from source to sink (Biju,1989).

5.6 PLANT HEIGHT, NUMBER OF TILLERS PER PLANT, LAI AND L: S RATIO OF FODDER GRASSES

5.6.1 Plant height

It was seen that the treatments had significant influence on the plant height of fodder grasses. BN hybrid recorded the maximum plant height among the fodder grasses in both harvests (Plate 5). BN hybrid is a clump grass, with erect nature where as palisade grass is a spreading grass which explains the difference in plant height between two grasses.

The treatment cassava + BN hybrid + AMF recorded maximum plant height in first harvest and was on par with cassava + BN hybrid +fodder cowpea+ AMF (T_8) and sole BN hybrid (T_{12}). Inoculation of AMF might have helped the grass for greater utilization of environmental resources which in turn might have resulted in increased plant height (Kavitha, 1996). Increased nutrient uptake at this stage due to AMF inoculation might have also resulted in increased plant height (Marschner and Dell, 1994).

During the second harvest also maximum height was recorded for cassava + BN hybrid + fodder cowpea + AMF. This may be due to the stimulatory effects

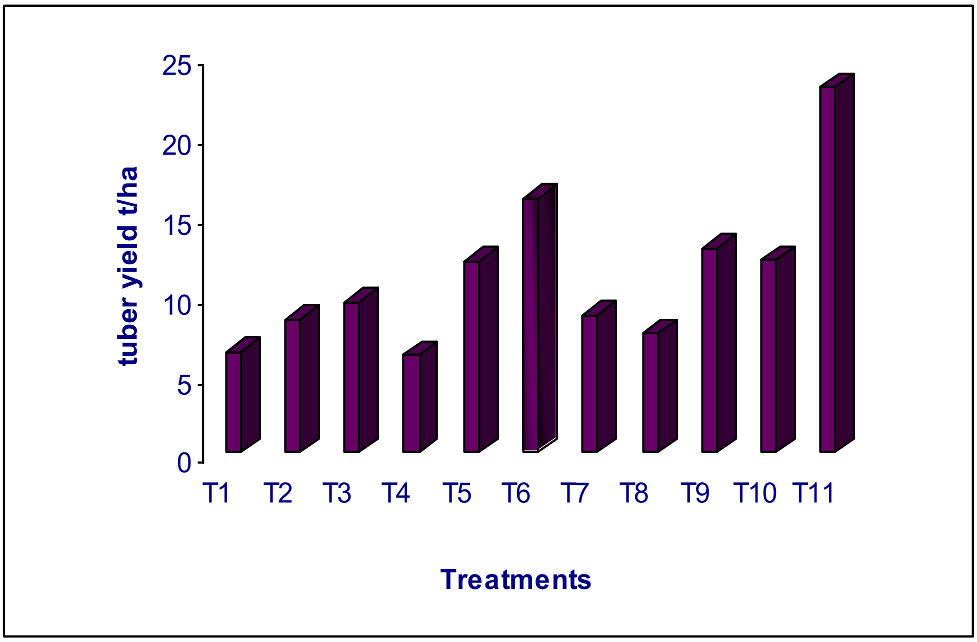


Fig.4 Tuber yield (t ha^{-1}) of cassava.

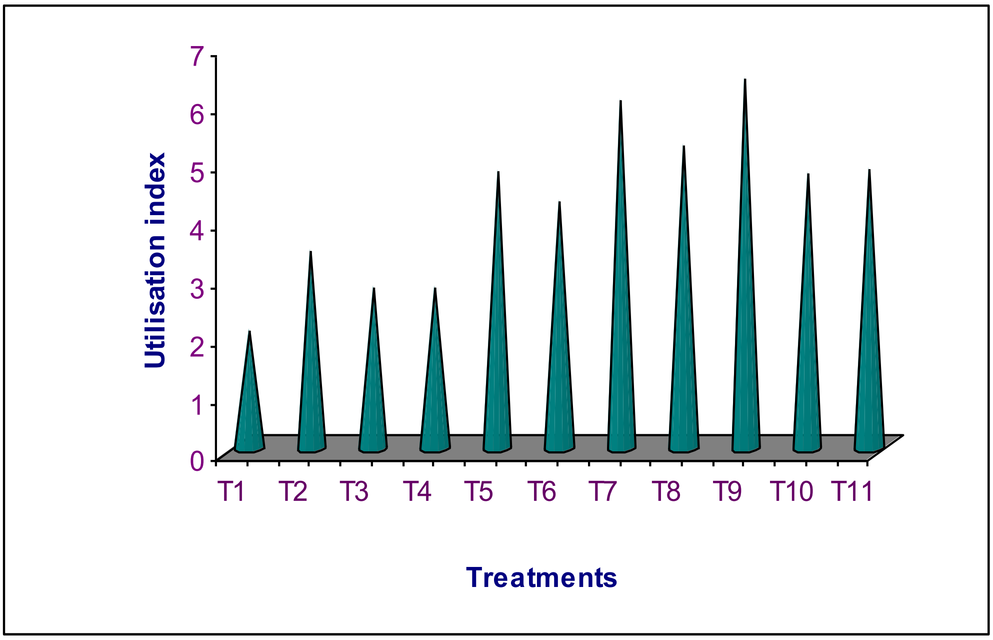


Fig.5 Utilization index of cassava

Plate 5 Cassava +BN hybrid at different stages of cassava growth.

of legume and AMF. Jayakumar (1997) reported that mean height of the BN hybrid was significantly increased in presence of legume intercrop. The result was on par with the treatments cassava + BN Hybrid + fodder cowpea and cassava + BN Hybrid + AMF which indicate either the presence of a fodder legume or mycorrhizal inoculum can improve the growth of BN hybrid. Lowest plant height was recorded by sole crop of palisade grass followed by cassava + palisade grass in both the harvest which is due to the spreading nature (Plate 6). This character of palisade grass makes the system less competitive for solar radiation. Along with cowpea and AMF, the plant height of palisade grass was increased. The positive influence of AMF on plant height of fodder grasses has been confirmed by Siqueira et al. (1990); Kavitha (1996) and George (1996).

5.6.2 Number of tillers per plant

Significant difference was seen on the number of tillers of fodder grasses in the two harvests. Palisade grass produced more number of tillers than BN hybrid and sole crop of palisade grass recorded maximum number of tillers in both harvests which was comparable to other alley crop combinations involving palisade grass viz. cassava + palisade grass (T_3), cassava + palisade grass + AMF (T_4), cassava + palisade grass + fodder cowpea (T_9) and cassava + palisade grass + fodder cowpea + AMF (T_{10}). Difference in tiller production of the grass may be due to their varietal difference.

Higher number of tiller production in sole crop of palisade may be attributed to the availability of more space and nutrients in the sole crop plots. Tiller production was found to be increased in palisade grasses when grown along with fodder cowpea due to the beneficial effect of legume. Similar results were obtained by Jayakumar (1997). More number of tillers was produced by palisade grass inoculated with AMF in the first harvest which may be due to the increased nutrient uptake. Tiller production was found to be increased in both grasses in the second harvest which may be due to the 46 percent more rainfall received during

Plate 6 Cassava + palisade grass at 4 MAP of cassava.

this period compared to the period of first harvest. The application of AMF had no influence on the number of tillers plant^{-1} of fodder grasses.

5.6.3 LAI

The treatments could not exert any significant influence on LAI of fodder grasses. Hence both the fodder grasses were similar with respect to solar energy utilization. The LAI of alley cropped grasses were comparable to that of the respective sole cropped grasses indicating the high photosynthetic efficiency that existed in alley cropped treatments.

5.6.4 L: S ratio of fodder grasses

It was observed from the results that L: S ratio was significantly influenced by the treatments. Alley crop combinations of BN hybrid viz. cassava + BN hybrid (T_1), cassava + BN hybrid + AMF (T_2) and cassava + BN hybrid + fodder cowpea (T_7) recorded higher L: S ratio on par with sole BN hybrid (T_{12}). This may be due to higher proportion of leaf in the BN hybrid grass which accounted for the leaf dry matter yield. Highest L: S ratio was observed for cassava + BN hybrid + fodder cowpea in the first harvest. In the second harvest cassava+ BN Hybrid + AMF recorded highest L: S ratio. The results indicated that all the alley cropping treatments with BN hybrid were comparable with sole crop of BN hybrid and similarly for palisade grass also, the sole crop of palisade grass was on par with the alley cropped treatments involving palisade grass. Hence all alley cropped treatments are as good as their respective sole crop treatments with respect to L: S ratio. The application of AMF had no influence on the L: S ratio of fodder grasses.

5.7 GREEN FODDER YIELD AND DRY FODDER YIELD OF FODDER GRASSES

5.7.1 Green fodder yield

The results of the present study indicated that green fodder yield was significantly influenced by the treatments in the first harvest (Fig.6). Among the fodder grasses, BN hybrid produced maximum green fodder yield during the first harvest which can be attributed to the significantly higher plant height and L: S ratio of the grass.

Maximum green fodder yield was obtained from the sole crop of BN hybrid on par with cassava + BN hybrid + AMF in the first harvest. In sole crop, yield was high due to more favourable conditions, more penetration of light, more fertile area available under sole crop under competition free environment.

In case of BN hybrid with AMF, the presence of AM Fungi increased the availability of nutrients, increased the nutrient uptake and there by promoted better growth of the grass resulting in production of same yield as the sole crop. This is evident from the highest plant height and tiller production recorded by T_2 which might have contributed to the yield. In the cassava based alley cropping system BN hybrid is found to be a high yielder than palisade grass.

Green fodder yield of the grass was higher in T_7 in the second harvest and for sole BN hybrid followed by T_7 for the cumulative green fodder yield of the two harvests. An increase in the yield was observed in the second harvest and for the cumulative yield, when grasses were grown with fodder cowpea which may be due to the complementary effect of the legume. Njoka-Njiru et al. (2006); Katoch and Marwah (2006) and Reddy and Naik (1999) obtained similar results.

5.7.2 Dry fodder yield

Dry fodder yield was found to be significantly influenced by the treatments in both harvests (Fig.7). In the first harvest sole crop of both the fodder grasses recorded the maximum dry fodder yield. In sole crop plots more nutrients were available for the re growth of the grass compared to the alley cropped plots where a part of the nutrients might be taken by the other crops resulting in poor growth of the grass.

Palisade grass + fodder cowpea alley cropped with cassava recorded highest dry fodder yield of grasses in second harvest. Similar results were reported by Choubey et al.(1997). Presence of a legume might have favourably influenced the dry matter production of palisade grass in cassava + palisade grass + fodder cowpea (T_9). Jayakumar (1997) reported that legume intercropping has a favourable influence on dry matter production of grasses. Total yield of the two harvests also showed significant difference which might be due to the significant difference in the first and second harvest. The application of AMF had no influence on the dry fodder yield of fodder grasses.

5.8. PLANT HEIGHT, NUMBER OF BRANCHES PER PLANT, NUMBER OF LEAVES PER PLANT, LAI AND L: S RATIO OF FODDER COWPEA.

Growth attributes of fodder cowpea showed variation among the treatments, but the effect was not statistically significant. But among the fodder grass + fodder cowpea alley crop combinations, all the yield attributes viz. plant height, number of branches plant^{-1}, number of leaves plant $^{-1}$ and LAI were higher in T_9 (cassava + palisade grass + fodder cowpea). Biju (1989), and Anilkumar et al. (1990) obtained similar result.

The application of AMF had no influence on the plant height, number of branches plant^{-1}, number of leaves plant $^{-1}$ and LAI of fodder cowpea.

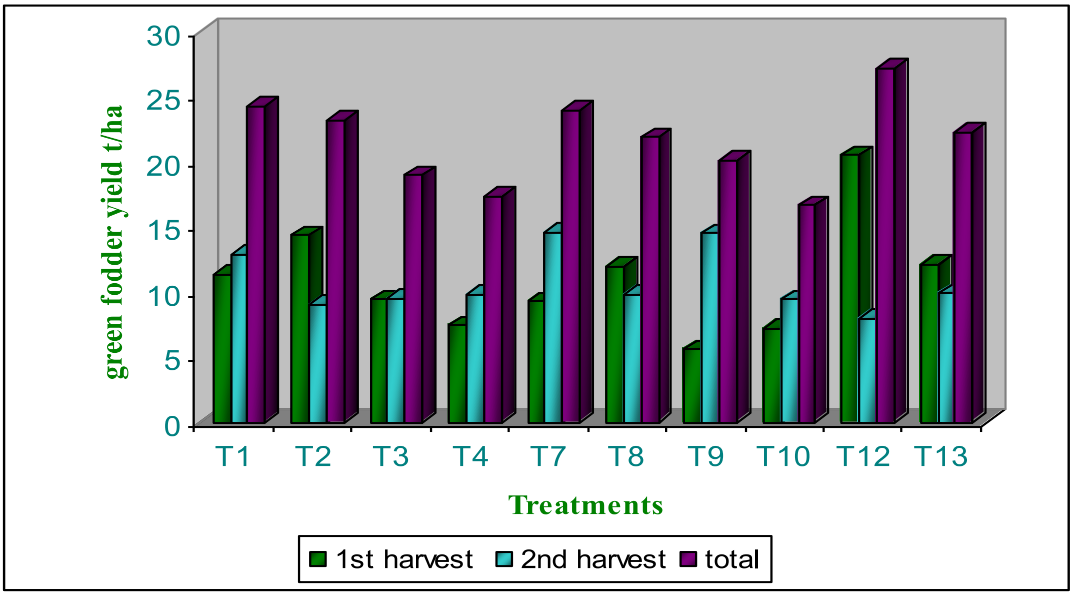


Fig. 6 Green fodder yield (t ha^{-1}) of fodder grasses

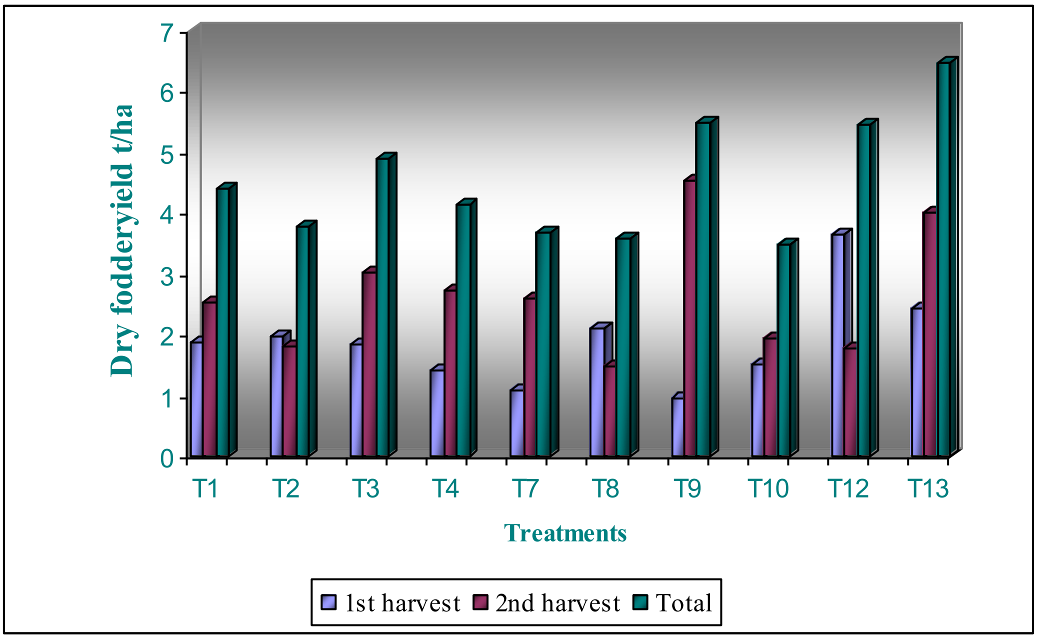


Fig.7 Dry fodder yield (t ha^{-1}) of fodder grasses

5.9 GREEN FODDER YIELD AND DRY FODDER YIELD OF FODDER COWPEA

5.9.1 Green fodder yield

Sole crop of fodder cowpea produced significantly high green fodder yield which was on par with cassava + fodder cowpea with AMF (T_6) followed by T_9 (cassava + palisade grass + fodder cowpea) (Fig.8). Higher plant population in sole crop and cassava + fodder cowpea plots might have contributed to the significant variation in the yield. Lowest yield in the cassava + BN Hybrid + fodder cowpea plot may be due to high competition effect and shading of BN hybrid.

The application of AMF had no influence on the green fodder yield of fodder cowpea.

5.9.2 Dry fodder yield

Dry fodder yield was also significantly influenced by the treatments. Sole crop of cowpea was found to be significantly superior to the others with maximum dry fodder yield (Fig.9).

Favourable growth conditions in sole crop plots and higher plant population may have contributed to their high dry matter production of plants Sheela et al. (1996) also obtained high dry fodder yield in sole crop of fodder cowpea.

5.10 GREEN FODDER YIELD AND DRY FODDER YIELD OF THE SYSTEM

Sole BN hybrid, combinations of cassava + BN hybrid without and with AMF (T_1 and T_2), cassava + BN hybrid + fodder cowpea without and with AMF (T_7 and T_8), sole palisade grass and cassava + palisade grass + fodder cowpea (T_9) recorded the highest total green fodder yield of the system, which can be

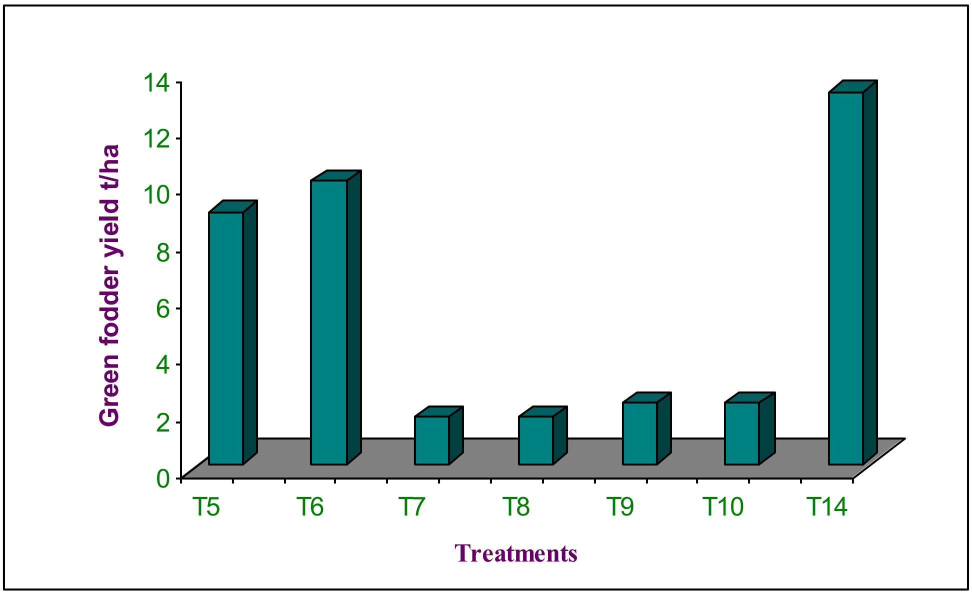


Fig. 8 Green fodder yield (t ha^{-1}) of fodder cowpea

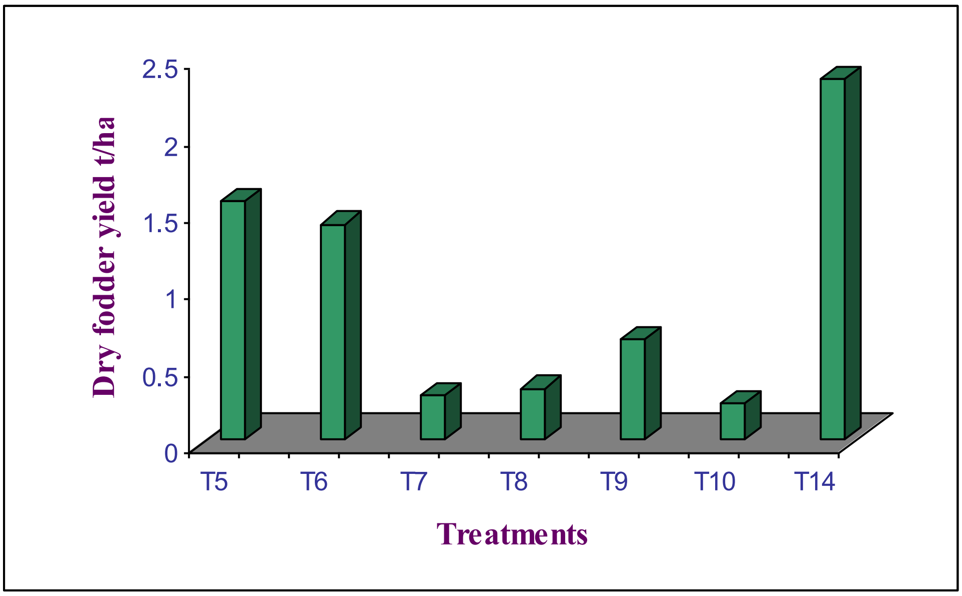


Fig. 9 Dry fodder yield (t ha^{-1}) of fodder cowpea

attributed to the ideal soil conditions for plant growth and green matter production as evidenced by significantly higher plant height, L: S ratio and green fodder yield in individual harvests for BN hybrid and number of tillers and green fodder yield in individual harvests for palisade grass.

Highest total dry fodder yield of 6.45 t ha^{-1} was obtained from T_{13} (sole palisade grass) which was on par with cassava + palisade grass + fodder cowpea (T_9), cassava + palisade grass (T_3) and sole palisade grass (T_{12}) since these combinations with palisade grass as the grass component recorded significantly higher dry fodder yield for the individual harvests..

5.11 QUALITY STUDIES.

5.11.1 Crude protein content of fodder grasses

All the treatments were comparable with respect to crude protein content. Sole crop of BN hybrid registered high crude protein content compared to the other treatments. Non significance in the crude protein content of the grasses may be due to the non significance in their nitrogen content. Crude protein content of the palisade grass was found to be influenced by legume intercropping though the effect was not significantly higher. Presence of legume in the plot may have enhanced the nitrogen uptake by the grasses resulting in an increase in the crude protein content. Similar results were also reported by Thomas (2003); Gupta et al. (2007) and Njoka - Njiru et al. (2006).

5.11.2 Crude protein content of fodder cowpea

Crude protein content of fodder cowpea was found to be not influenced by alley cropping or AMF application indicating that crude protein content is a varietal character and not influenced by the treatments.

5.11.3 Crude protein yield of the system

Alley cropping palisade grass and fodder cowpea in cassava produced the highest crude protein yield in the system which was on par with sole BN hybrid, palisade grass and fodder cowpea (T_{12}, T_{13} and T_{14} respectively) and which was 19.81 percent and 23.33 percent higher than the respective sole crop crude protein yields of palisade grass and fodder cowpea.

Hence this combination of cassava + palisade grass + fodder cowpea (T_9) was the most efficient cropping system in this study with respect to quality feed production.

5.12 NUTRIENT UPTAKE STUDIES

5.12.1 Nutrient uptake by cassava

There was no significant difference between treatments with respect to uptake of nitrogen, phosphorus and potassium by cassava. The uptake of nitrogen and potassium was maximum in plots where cassava was grown along with fodder cowpea without AMF. Neither the effect of alley cropping or AMF on nutrient uptake of cassava was found to be significant. Low influence of AMF on the nutrient uptake of cassava may be due to high phosphorus status of the soil.

Response of cassava to VAM inoculation is maximum when the available P was in the medium level. In the soil and at low and high levels of available P, the response was very poor (Sivaprasad et al., 1989). Depression of AM fungal colonization levels by high soil P concentration are often observed Barea (1991) and Marschner and Dell (1994). The dependency of plants for undergoing AM association varies as plant species differ in their P requirement (Gupta et al., 2007).

5.12.2 Nutrient uptake by fodder grasses

Higher nitrogen, phosphorus and potassium uptake was recorded by sole crop of BN hybrid which is due to the higher plant population on sole crop. Even though statistically not significant, in general uptake of all the nutrients was higher in AMF applied plots compared to the respective treatments without AMF except for cassava + palisade grass. This is due to the development of extensive network of hyphae by AMF, which might have increased the uptake. Similar results were also obtained by Kavitha (1996).

Marschner and Dell (1994) have opined that a greater uptake of nutrients by mycorrhizal plants can be attributed not only to the uptake through fungal hyphae but also to the increased root growth.

5.12.3 Nutrient uptake by fodder cowpea

Sole crop of fodder cowpea registered maximum uptake of all nutrients and was significantly superior to other treatments (Fig.10).

The significant difference in nutrient uptake can be attributed to higher plant population in sole crop and lack of competition due to cassava and fodder grasses. Significant effect of AMF was observed in case of phosphorus uptake for cassava + fodder cowpea which may be due to the extension of root system by the influence of AMF.

5.12.4 Total nutrient uptake

Total uptake of all nutrients showed significant difference among the treatments (Fig.11). Significantly higher uptake of N was recorded in sole fodder cowpea and in treatments where cassava was alley cropped with fodder cowpea along with the two fodder grasses. This may be due to increased availability of N

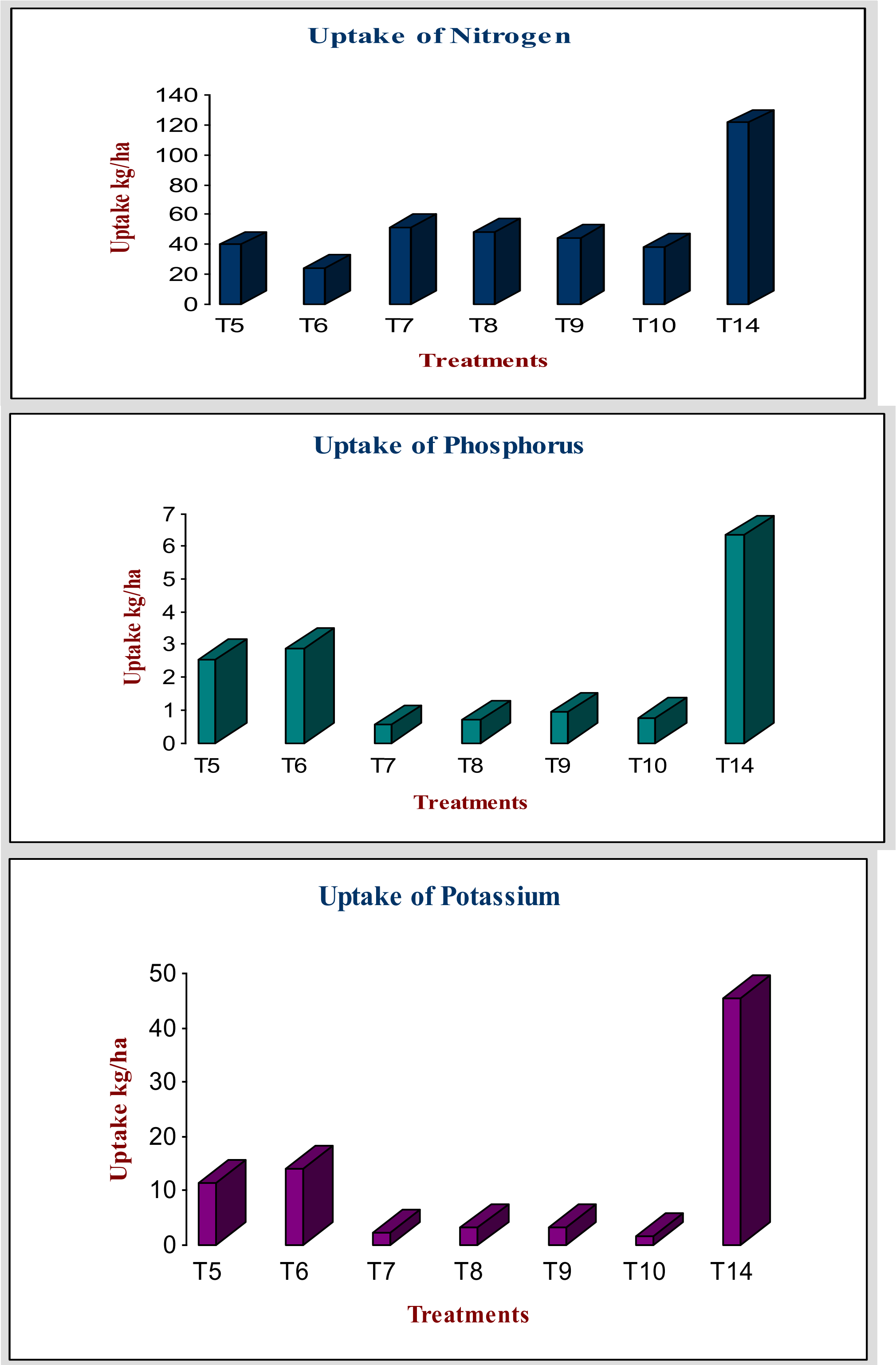


Fig.10 Nutrient uptake of fodder cowpea (kg ha^{-1}).

due to fixation by cowpea. Sole crop of BN hybrid along with the combinations of cassava + BN hybrid + fodder cowpea registered significantly higher P uptake. Similarly, sole crop of BN hybrid along with the combinations of cassava + BN hybrid + fodder cowpea registered significantly higher K uptake which was comparable to the potassium uptake in sole palisade grass, cassava + palisade grass combinations and cassava + palisade grass + fodder cowpea + AMF treatment.

5.13 SOIL NUTRIENT STATUS AFTER EXPERIMENT

Nutrient status of the soil after the experiment was not significantly influenced by alley cropping except for the organic carbon content. High nitrogen content was recorded in the plot of sole crop of fodder cowpea followed by cassava + fodder cowpea with and with out AMF which may be due to nitrogen fixation by legumes. Similar results were obtained by Kavitha (1996). Phosphorus content in the soil after the experiment was low in AMF applied plots compared to respective treatments without AMF application which may be due to higher uptake by plants.

5.14 BIOLOGICAL EFFICIENCIES

The LER of the system was seen to be not influenced by the treatments. However the total LER values of all the treatments were more than one, indicating that alley cropping in cassava is advantageous. Similarly almost all treatments recorded a LEC value greater than 0.25, except cassava + palisade grass + fodder cowpea with and without AMF, indicating that the system has yield advantage. The treatment cassava + palisade grass + fodder cowpea recorded highest LER value of 1.70. But the LEC values which is regarded as a measure of interaction, when concerned with the strength of relationship, was less than 0.25 in these treatments. Cassava + fodder cowpea + AMF produced the highest LEC value of 0.56 and also an LER of 1.47, which proves that the combination is efficient. The

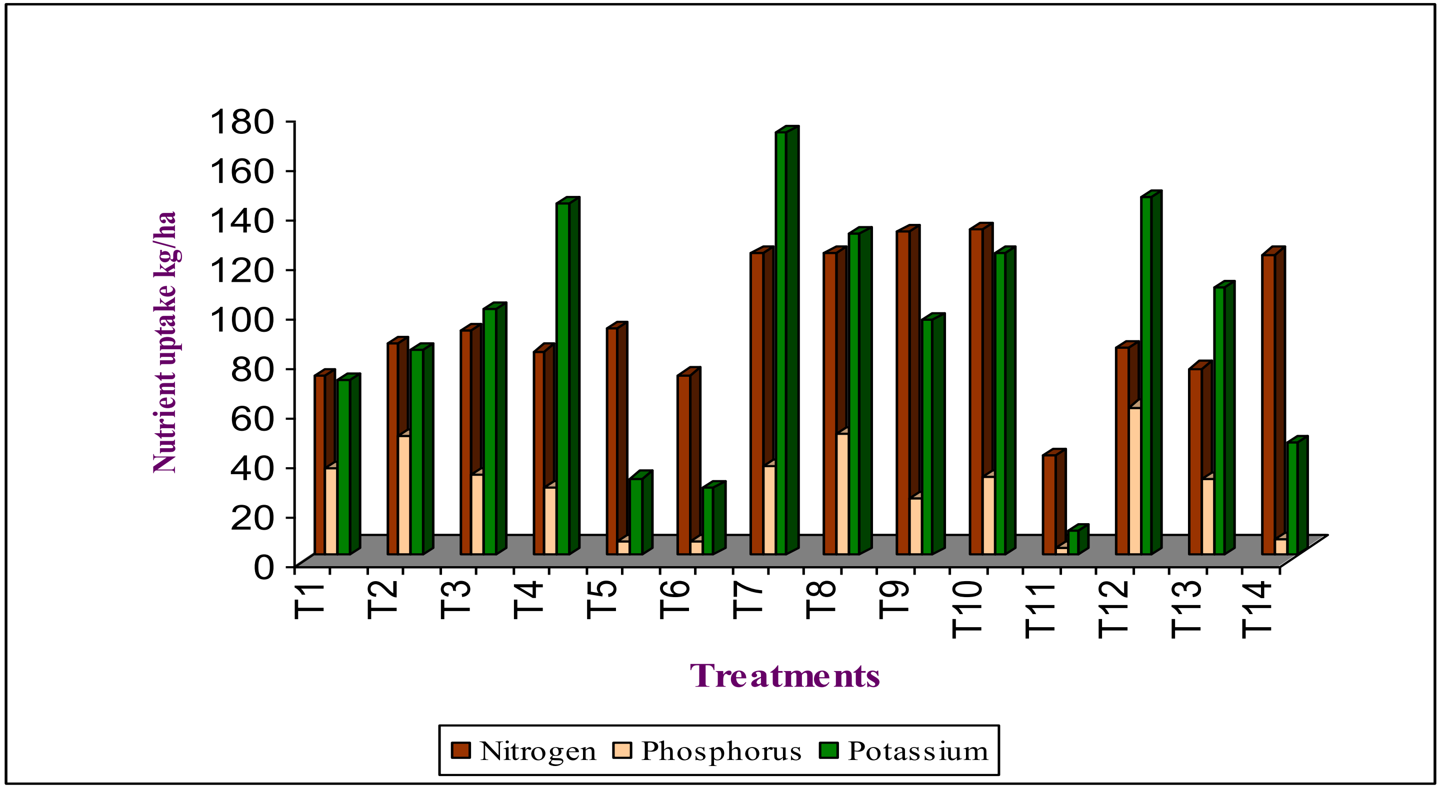


Fig:11 Total nutrient uptake (kg ha^{-1}

LER value of 1.47 indicates that 47 percent more area is required as sole crop to produce the same yield as in alley cropping ie. 47 percent more efficiency was obtained by alley cropping cassava with fodder cowpea compared to sole crops.

Positive value of aggressivity for fodder grasses and fodder cowpea showed that the fodder crops are more aggressive and have high competitive ability than cassava. Among the grasses, BN hybrid was more aggressive (Plate 7). Highest cassava equivalent yield (Fig.12) was recorded by the sole cassava which was on par with cassava + fodder cowpea and cassava + palisade grass + fodder cowpea indicating that fodder cowpea is the most efficient intercrop in cassava compared to fodder grasses, followed by cassava + palisade grass + fodder cowpea indicating the suitability of this alley crop combination in cassava (Plate 8).

5.15 ECONOMICS OF ALLEY CROPPING IN CASSAVA

The treatment cassava + palisade grass with and with out AMF recorded the highest annual gross returns. But because of the high cost of cultivation in these treatments, the net returns were less than that in the sole crop of cassava (Fig13), where the cost of production was low.

B: C ratio, more than one obtained for alley cropped treatments except T_4 and T_8 (Fig14) indicates that alley cropping in cassava is economical. However highest B: C ratio was obtained for sole cassava, which is due to the low cost of production in sole crop plots.

Highest cassava equivalent yield of 22.95 t ha^{-1} was recorded by T_{11} (sole cassava) which was on par with T_6 (cassava + fodder cowpea + AMF), T_9 (cassava + palisade grass + fodder cowpea) and T_{10} (cassava + palisade grass + fodder cowpea + AMF). Hence cassava + fodder cowpea + AMF and cassava + palisade grass + fodder cowpea combinations are better options for alley cropping.

Cassava+B N hybrid

Cassava+B N hybrid+ Fodder cowpea

Plate 7 Cassava + BN hybrid combinations at 2 M A P

2 MAP

4 MAP

Plate 8 Cassava+Palisade grass + Fodder cowpea at different stages of cassava growth

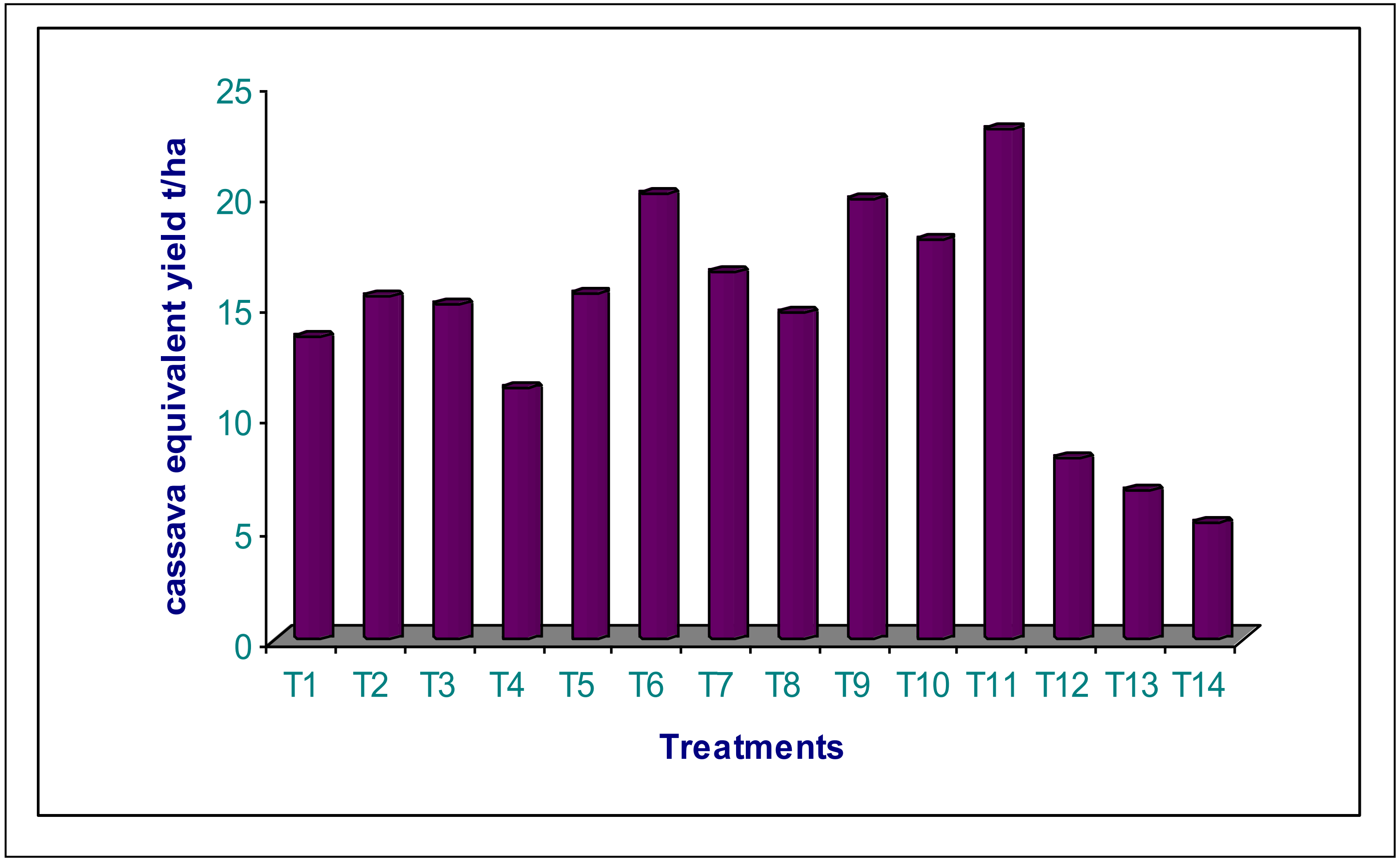


Fig. 12 Cassava equivalent yield (Kg ha^{-1}).

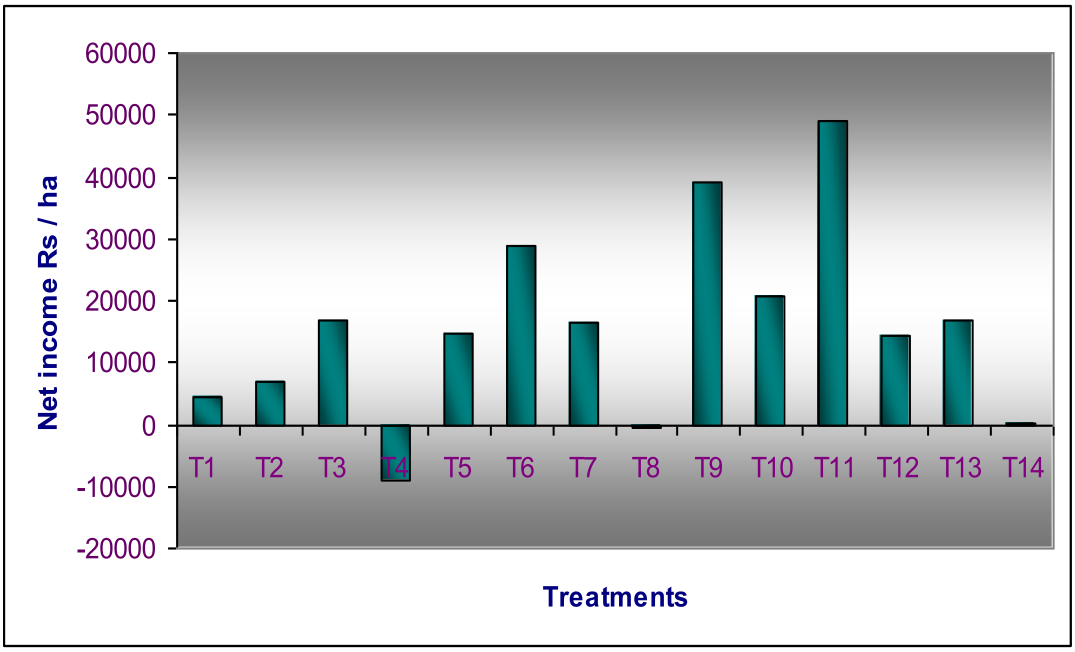


Fig. 13 Economics of alley cropping in cassava

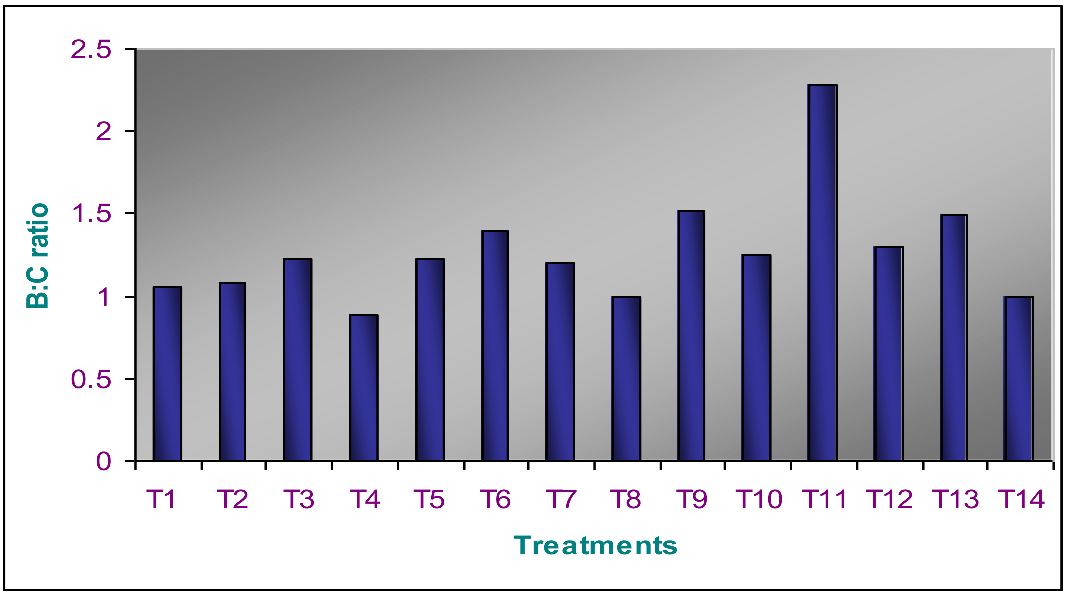


Fig. 14 B: C ratio

The cassava equivalent income of sole cassava (T_{11}) was the highest (Rs.114766 ha^{-1}) and was on par with that of cassava + fodder cowpea + AMF (Rs.100033 ha^{-1}), cassava + palisade grass + fodder cowpea (Rs. 98936 ha^{-1}) and cassava + palisade grass + fodder cowpea +AMF (Rs.89855 ha^{-1}) which indicates the economic superiority of these combinations.

5.16. EFFECT OF ALLEY CROPS AND AMF ON BIOLOGICAL, ECONOMIC AND LAND USE EFFICIENCY OF THE SYSTEM

The cassava equivalent yield and cassava equivalent income did not show any significant difference between the treatments with respect to alley crops. But the LER values were significantly higher for the palisade grass + fodder cowpea and fodder cowpea combinations which indicate the superiority for land use, which is of high value in intercropping systems. Similar results were obtained by Bai et al. (1992b); Jayakumar (1997); Amanullah et al. (2007a) and Polthane et al. (2007).

The application of AMF had no influence on the biological, economical and land use efficiency of the system. The alley crop AMF interaction effects were non significant for cassava equivalent yield, cassava equivalent income and LER.

5.17 BIOLOGICAL, ECONOMIC AND LAND USE EFFICIENCY OF THE SYSTEM

The biological productivity and economic efficiency of the system were highest in sole crop of cassava which was on par with cassava with fodder cowpea and cassava with palisade grass and fodder cowpea. Alley cropping cassava with palisade grass and fodder cowpea resulted in significantly higher crude protein yield. The LER values of system indicate that alley cropping in cassava is advantageous. The highest LER of (1.70) of the system was recorded in T_9 (cassava + palisade grass + fodder cowpea).

Considering the total biological productivity, quality and economic efficiency the combination of cassava + palisade grass + fodder cowpea is found to be more efficient for food-fodder production.

Summary

6. SUMMARY

A field experiment was conducted to asses the bio and economic suitability of raising fodder grasses and legumes in the alleys of cassava for food - fodder production and to study the response of the system to AMF application at the Instructional Farm attached to the College of Agriculture, Vellayani during 2009. The experiment with fourteen treatments was laid out in Randomized Block Design with three replications. The results obtained are summarised below.

Plant height and leaf production of cassava was significantly influenced by the treatments and sole crop of cassava recorded maximum plant height and maximum number of leaves at 6 MAP due to the favourable environmental conditions in the sole crop plots. Alley crop combinations of palisade grass, fodder cowpea or their combinations were responsible for significantly higher LAI in cassava, which indicates the suitability of these crops in alley cropping in cassava.

Yield attributes of cassava viz. tuber number plant $^{-1}$, length and girth of tuber were not influenced by alley cropping. Highest number of tubers plant^{-1} was obtained for cassava + palisade grass + fodder cowpea + AMF. Sole cassava recorded the maximum tuber length and highest tuber girth was recorded by cassava + BN hybrid + AMF.

Tuber yield of cassava was significantly influenced by alley cropping. Sole crop of cassava registered highest tuber yield followed by cassava + fodder cowpea + AMF. Among the fodder grasses cassava grown along with BN hybrid produced comparatively low yield. There was 62.23 percent reduction in tuber yield of cassava due to BN hybrid + fodder cowpea alley cropping. When palisade grass + fodder cowpea was alley cropped in cassava the tuber yield reduction recorded was only 43.90 percent. Hence palisade grass is a better

fodder grass component for alley cropping in cassava compared to BN hybrid. The application of AMF had no influence on the growth attributes, yield attributes and tuber yield of cassava.

Plant height and number of tillers plant^{-1} of fodder grasses were significantly influenced by the treatments in the first and second harvests. Lowest plant height was recorded by sole crop of palisade grass followed by cassava + palisade grass in both the harvest which is due to its stoloniferous nature. This character of palisade grass makes the system less competitive for solar radiation. BN hybrid recorded the maximum plant height among the fodder grasses in both harvests.

In both harvests maximum number of tillers was produced by sole palisade grass. Tiller production was increased in palisade grasses when grown along with fodder cowpea. LAI of fodder grasses did not show any significant difference between the treatments in both harvests. Highest L: S ratio was observed for cassava + BN hybrid + fodder cowpea in the first harvest. In the second harvest cassava + BN Hybrid + AMF recorded highest L: S ratio. All alley cropped treatments are as good as their respective sole crop treatments with respect to L: S ratio.

The treatments had significant influence on green fodder yield at first harvest. In the first harvest, sole BN hybrid produced maximum green fodder yield of 20.54 t ha^{-1} which was on par with cassava + BN hybrid + AMF with 14.35 t ha^{-1} of green fodder yield. Green fodder yield of the grasses did not vary significantly in the second harvest and also for the cumulative green fodder yield of the two harvests. Highest total dry fodder yield of 6.45 t ha^{-1} was obtained from sole palisade grass on par with T_9, T_{12} and T_3 from two harvests.

Growth attributes of fodder cowpea did not show any significant difference between the treatments. Sole fodder cowpea crop registered maximum green fodder yield of 13.14 t ha^{-1} which was on par with T_6 (10.02 t ha^{-1}) and T_5 (8.9 t ha^{-1}) from two harvests. In case of total dry fodder yield also sole fodder cowpea (2.34 t ha^{-1}) was significantly superior to all other treatments.

Sole BN hybrid and palisade grass recorded the highest total green fodder yield and dry fodder yield of the system respectively.

Alley cropping palisade grass and fodder cowpea in cassava produced the highest crude protein yield in the system which is 19.81 percent and 23.33 percent higher than the respective sole crop crude protein yields of palisade grass and fodder cowpea. Hence this combination is the most efficient in this study with respect to quality feed production.

Significantly higher uptake of N was recorded in sole fodder cowpea and in treatments where cassava was alley cropped with fodder cowpea along with the two fodder grasses. Sole crop of BN hybrid along with the combinations of cassava + BN hybrid + fodder cowpea registered significantly higher P uptake. Sole crop of BN hybrid along with the combinations of cassava + BN hybrid + fodder cowpea registered significantly higher K uptake which was comparable to the potassium uptake in sole palisade grass, cassava + palisade grass combinations and cassava + palisade grass + fodder cowpea + AMF treatment.

Nutrient status of the soil after the experiment was not significantly influenced by alley cropping except for the organic carbon content. High nitrogen content was recorded in the plot of sole crop of fodder cowpea followed by cassava + fodder cowpea with and with out AMF which is clearly due to nitrogen fixation by legumes. Highest phosphorus content and organic carbon content in the soil was recorded for the treatment cassava + palisade grass.

The treatment cassava + palisade grass + fodder cowpea recorded highest LER value of 1.70. Cassava + fodder cowpea + AMF produced the highest LEC value of 0.56 and also an LER of 1.47, which proves that the combination is efficient.

Positive value of aggressivity for fodder grasses and fodder cowpea showed that the fodder crops are more aggressive and have high competitive ability than cassava. Among the grasses, BN hybrid was more aggressive

Highest cassava equivalent yield was recorded by the treatment sole cassava on par with cassava + fodder cowpea + AMF indicating that fodder cowpea is the most efficient intercrop in cassava compared to fodder grasses, followed by cassava + palisade grass + fodder cowpea indicating the suitability of this alley crop combination in cassava. The fodder crops were found to be more aggressive and with high competitive ability than cassava.

The cassava equivalent income of sole cassava was the highest and was on par with that of cassava + fodder cowpea + AMF, cassava + palisade grass + fodder cowpea and cassava + palisade grass + fodder cowpea +AMF which indicates the economic superiority of these combinations.

Highest net income of Rs. 64507 ha^{-1} was obtained from sole crop of cassava (T_{11}) followed by cassava + palisade grass + fodder cowpea (T_9) with a net income of Rs.39,100 ha^{-1}. Highest B: C ratio of 2.28 was obtained for sole cassava (T_{11}) followed by cassava + palisade grass + fodder cowpea (T_9) (1.52).

The biological productivity and economic efficiency of the system were highest in sole crop of cassava which was on par with cassava with fodder cowpea and cassava with palisade grass and fodder cowpea. Application of AMF had no significant effect on the biological, economic and land use efficiency of the system. Considering the total biological productivity, quality, economics and land use efficiency, the combination of cassava + palisade grass + fodder cowpea is found to be more efficient for food-fodder production.

References

7. REFERENCES

Adetiloye, P.O., Ezedinma, F.O.C., and Okigbo, B.N. 1983. A land equivalent coefficient concept for the evaluation of competitive and productive interactions in simple complex mixtures. Ecol. Modelling, 19: 27-39.

Alves, A.A.C. 2003. Cassava - botany and physiology In. Cassava Biology, Production and Utilization. Hillock, R.J., Thresh, J.M., and Bellotti, A.C. (eds) CABI. Publishing, 332p.

Amanullah, M.M., Alagesan, A., Vaiyapuri, K., Pazhanivelan, S., and Sathyamoorthi, K. 2006a. Effect of intercropping and organic manures on the growth and yield of cassava (*Manihot esculenta* Crantz.). Research J. Agric. Biol. Sci., 2(5): 183-189.

Amanullah, M.M., Vaiyapuri, K., Alagesan, A., Somasundaram, E., Sathyamoorthi, K., and Pazhanivelan, S. 2006b. Effect of intercropping and organic manures on the yield and biological efficiency of cassava intercropping System (*Manihot esculenta* Crantz.). Research J. Agric. Biol. Sci., 2(5): 201-208.

Amanullah, M.M., Somasundaram, E., Vaiyapuri, K., and Sathyamoorthi, K. 2007a. Intercropping in cassava - a review. Agric. Reviews, 28 (3): 179-187.

Amanullah, M.M., Sathyamoorthi, K., Vaiyapuri, K., Alagesan, A., and Pazhanivelan, S. 2007b. Influence of organic manures on the nutrient uptake and soil fertility of cassava (*Manihot esculenta* Crantz.) intercropping systems. International J. Agric. Res., 2 (2): 136-144.

Anilkumar, A.S. 1984a. Crop geometry studies in tapioca based intercropping system. M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur.116p.

Anilkumar, P. 1984b. Nitrogen economy and soil conservation in Tapioca – stylo intercropping system. M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur, 115 p.

Anilkumar, A.S., Nair, G.K.B., Sukumari, P., Lakshmi, S., Bai, M.M., and Pillai, G. R. 1990. Spatial arrangement and nutrient management in cassava - fodder cowpea intercropping system under rainfed condition. J. Root Crops, 17 (Special Issue): 147-150.

Atayese, M.O., Awotoye, O.O., Osonubi, O., and Mulongoy, K. 1993. Comparisons of the influence of vesicular arbuscular mycorrhiza on the productivity of hedgerow woody legumes and cassava at the top and the base of a hill slope in alley cropping systems. Biol. Fertility Soils, 16 (3): 198-204.

Bai, M.M., Babu, K.S., Girija, V.K., Sobhana, S., and Pushpakumari, R. 1990. Planting geometry and double intercropping in cassava - performance evaluation under rainfed agriculture in south Kerala. J. of Root Crops, 17 (Special Issue): 165-168.

Bai, M.M., Babu, K.S., Girija, V.K., Sobhana, S., and Pushpakumari, R. 1992a. Cassava-based intercropping systems for the homesteads of south Kerala. Crop Res. (Hisar), 5 (3): 520-524.

Bai, M.M., Babu, K.S., Girija, V.K., Sobhana, S., and Pushpakumari, R. 1992b. Planting geometry and double intercropping in rainfed cassava under the homestead farming system of South Kerala. Farming Sys., 8 (1-2): 12-17.

Balakrishnan, P and Thamburaj, S. 1993. Studies on tapioca based intercropping system under irrigated conditions of Salem district. South Indian Hort., 41(5): 273-277.

Barea, J.M. 1991. Vesicular arbuscular mycorrhizae as modifiers of soil fertility. Advances in soil science, 15.Springer Verlag Newyork.Inc.pp.1-40.

Biju, L. 1989. Planting geometry and double cropping in cassava. M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur.104p.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soil. Agron. J., 54: 404-405.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci., 59: 39-45.

Bridgit, T.K. 1985. Fertilizer management in cassava - groundnut intercropping system. M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur.132p.

Bridgit, T.K., Sreedharan, C., and Abraham, C.T. 1992. Nutrient uptake in cassava groundnut intercropping system. Orissa J. Agric. Res., 5 (3-4): 154-158.

Calderon, M. and Gonzalez, P.J. 2007. Guinea grass (*Panicum maximum*, cv. Likoni) response to arbuscular mycorrhizal fungus inoculation on a Lixiviated Red Ferralitic soil. Cultivos Tropicales, 28(3): 33-37.

*Charpentier, H., Rakotondramanana., Razanamparany, C., Andriantsilavo, M., Husson, O., and Seguy, L. 2006. Intercropping cassava with *Brachiaria sp.* on degraded hillsides in Madagascar. Congres Mondial d'Agriculture de Conservation, 3, 2005-10-03/2005-10-07, Nairobi, Kenya.

Chhabra, M.L., Singh, R.P., and Jalali, B.L. 1990. Studies on vesicular-arbuscular (VA) mycorrhizal impact on growth and development of cowpea (*Vigna unguiculata* (L.) Walp.). Trends in mycorrhizal research. Proceedings of the National Conference on Mycorrhiza, held at Haryana Agricultural University, Hisar, India, Feb. 14-16, 1990, pp150-151.

Choubey, S., Prasad, N.K., and Bhagat, R.K. 1997. Suitable grass-legume combination for higher forage production. J. Res. Birsa Agricultural University, 9(1): 81-83.

Dapaah, H.K., Ennin, S.A., and Asafu-Agyei, J.N. 2004. Performance of cassava intercropped with maize, soybean and cowpea in the forest zone of Ghana. J. Ghana Agric. Food Sci., 3:193-202.

Dung, N.T., Ledin, I., and Mui, N. T. 2005. Intercropping cassava (*Manihot esculenta* Crantz) with Flemingia (*Flemingia macrophylla*); effect on biomass yield and soil fertility. Livestock Research for Rural Development, 17(1): 64-66.

Eke-Okoro, O.N., Ikeorgu, J.E.G., and Okorocha, E.O.A. 1999. Comparative evaluation of five legume species for soil fertility improvement, weed suppression and component crop yields in cassava/legume intercrops. Afri. J. Root Tuber Crops, 3 (2): 17-54.

Ezumah, H.C. 1990. Maize (*Zea mays*) genotypes for intercropping with cassava (*Manihot esculenta*) in Southern Nigeria. I. Yield responses. Discovery and Innovation, 2: 65-72.

Fagbola, O., Osonubi, O., and Mulongoy, K. 1998. Growth of cassava cultivar TMS 30572 as affected by alley-cropping and mycorrhizal inoculation. Biol. Fertility Soils, 27: 9–14.

Ganesan, V. and Mahadevan, A. 1994. Effect of mycorrhizal inoculation on cassava, elephant foot yam and taro. J. Root Crops, 20(1): 1-14.

Geethakumari, V.L., Shivshankar, K., and Bagyaraj, D.J. 1990. Effect of organic amendment in conjunction with mycorrhiza on fingermillet. J. Soil Biol.Ecol., 10(2): 57-60.

George, S. 1996. Agronomic evaluation of bio farming techniques for forage production in coconut gardens. Ph.D Thesis. Kerala Agricultural University, Thrissur, 334 p.

Ghosh, S.P., Ramanujan, T., Jos, J.S., Moorthy, S. N., and Nair, R.G. 1988. Tuber Crops. Oxford and IBH publishing co.pvt.Ltd, 403 p.

Gill, A.S. and Gangwar, K.S. 1990. Evaluation of intensive forage production under guava (*Psidium guavajava* L.) plantation. Indian J. Agron., 35(4): 437-438.

Gill, A.S., Tripathi, S.N., and Gangwar, K.S. 1990. Effect of stand geometry on productivity of hybrid napier subabul association under agroforestry system. Indian J. Agron., 35 (4): 434-437.

Gomez, K.A. 1972. Techniques for field experiments with rice. Internatinal Rice Research Institute, Los Banos, Phillipines, p.33.

Gopalan, A., Raja, D., and Sudhagar, R. 2003. Associative cropping pattern that enhance the animal yield. Aspects Appl. Biol., 70: 137-141.

Graham, J.H. and Abbott, L.K. 2000. Wheat responses to aggressive and non aggressive arbuscular mycorrhizal fungi. Pl. soil, 220: 207-218.

Gupta, R.P. and Dakshinamoorthy, C. 1980. Procedures for plant physical analysis of soil and collection of agrometeorological data, IARI. NewDelhi, p.280.

Gupta, P.P., Rakesh, K., and Jalali, B.L. 1999. Response of different vesicular-arbuscular mycorrhizal fungi on cowpea. Plant Disease Res., 14 (1): 25-30.

Gupta, R.P., Anu, K., and Shammi, K. 2007. Bio inoculants - A step towards sustainable agriculture. New India Publishing agency. New Delhi, p.139-181.

Harrier, L.A and Watson, C.A. 2003. The role of arbuscular mycorrhizal fungi in sustainable cropping systems. Advances in Agronomy. Ed. N.C.Brady 79:185-225.

Hazra, C.R. 1994. Response of bio fertilizer in forage and fodder crops. Fertil. News, Vol 39(4): 43-53.

Howeler, R.H. 1989. Phosphorus requirements and management of tropical root and tuber crops. Phosphorus requirements for sustainable agriculture in Asia and Oceania. Proceedings of a symposium, 6-10 March. pp 427-444.

Jackson, M.L. 1973. Soil chemical Analysis. Prentice Hall of India. pvt Ltd. New Delhi, p.498.

Jacobsen, I. 1994. Research approaches to study the functioning of vesicular arbuscular mycorrhizae in the field. Pl. Soil, 159:141-147.

Jagtap, S.S., Alabi, R.T., and Adeleye, O. 1998. The influence of maize density on resource use and productivity. An experimental and stimulation study. J.Agron. Crop Sci., 6 (3): 259-272.

Jayakumar, G. 1997. Intensive fodder production through legume inter cropping in hybrid napier. M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur. 130p.

Johansen, A., Jakobson, I., and Jensen, E.S. 1993. Hyphal transport by a vesicular arbuscular mycorrhizal fungi in irradiated soil. Pl. Soil, 78: 315-323.

Kahlon, C.S. and Sharanappa, R.K. 2006. Effect of phosphorus, zinc, sulphur and bio inoculants on yield and economics of cowpea. Mysore J. Agric. Sci., 40 (1): 138-141.

Kang, B.T., van der Kruijs, A.C.B.M., and Cooper, D.C. 1989. Alley cropping for food production. (In) Alley Farming in the Humid and Sub-humid Tropics. Kang, B.T. and Reynolds, L. (eds). Ottawa, Canada: International Development Research Centre, pp. 16-26.

Kang, B.T., Reynolds, L., and Attakrah, A.N. 1990. Alley farming. Advances in Agronomy,.Ed.N.C.Brady.43: 316-352.

Kanno, T., Saito, M., Ando, Y., Macedo, M.C.M., Nakamea, T., and Miranda, C.H.B. 2006. Importance of indigenous arbuscular mycorrhiza for growth and phosphorus uptake in tropical forage grasses growing on an acid, infertile soil from the Brazilian savannas .Tropical grasslands, 40 (2): 94-101.

Karnik, A.R., Apte, U.B., Jadhav, B.B., and Wagh, R.G. 1993. Intercropping legume and vegetable in rainfed cassava (*Manihot esculenta* Crantz.). Indian J. Agric. Sci., 63(5): 265-267.

Katoch, R.S B. S. and Marwah, C. L. 2006. Intercropping of forage crops with grasses - an innovative fodder production system for mid-Himalayan hills. Range Manage. Agroforest., 27 (1): 13-17.

Kavitha, P.K. 1996. Nutrient management with bio fertilizers in a fodder maize – cowpea intercropping system. M.Sc. (Ag) thesis. Kerala Agricultural University. Thrissur. 126p.

Kumar, C.R.M. and Ravindran, C.S. 1991. Economics of intercropping short duration legumes and vegetables with cassava J. Root Crops, 17 (Special Issue): 120-122.

Kumari, R.V., Nanjundappa, G., and Hattappa, S. 2008a. Drumsticks in horti-pasture system under protective irrigation. Environ. Ecol., 26(1A): 465-466.

Kumari, R. V., Nanjundappa, G., and Hattappa, S. 2008b. Drumsticks vs Fodder grass under horti – pasture system. Environ. Ecol., 26(1A): 472-473.

Lakshmi, S., Devi, L.G., Nair, M.A., and Vidya, C. 2002. Yield and economics of fodder legume -hybrid napier intercropping systems. Forage Res., 28 (1): 13-15.

Leihner, D.E., Ruppenthal, M., Hilger, T. H., and Castillo, F. J. 1996 .A Soil conservation effectiveness and crop productivity of forage legume intercropping, contour grass barriers and contour ridging in cassava on Andean hillsides. Exptl. Agric., 32 (3): 327-338.

Lu, X. and Koide. 1994. The effects of mycorrhizal infection on components of plant growth and reproduction. New Phytologist, 128: 211-218.

Mali, B.L., Rakesh, S., and Dharmendra, S. 2009. Response of cowpea (*Vigna unguiculata*) varieties and varying levels of phosphorus on VA-mycorrhizal (*Glomus fasciculatum*) colonization and nutrient uptake. J. Plant Disease Sci., 4 (1): 79-83.

Marschner, H. and Dell, B. 1994. Nutrient uptake in mycorrhizal symbiosis. Pl. Soil, 159: 89-102.

Mc Gilchrist, C.A. 1965. Analysis of competition experiments. Biometrics, 21: 975-985.

Mead, R. and Willey, R.W. 1980. The concept of land equivalent ratio and advantages in yield from intercropping. Exptl. Agric., 16: 217-228.

*Miranda, J.C.C.de., Fialho, J.de.F., and Miranda, L.N.de. 2005. The importance of arbuscular mycorrhiza for cassava cropping in the cerrado soils. Comunicado Tecnico - Embrapa Cerrados, 119: 4 pp.

Mutsaers, H.J.W., Ezumah, H.C., and Osiru, D.S.O. 1993. Cassava-based intercropping: a review. Field Crops Res., 34 (3/4): 431-457.

Narayanan, S. 1991. Nutrient uptake efficiency of cassava (*Manihot esculenta* Crantz.) as influenced by Vesicular Arbuscular Mycorrhizal (VAM) association and rock phosphate application. M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur.124p.

Narayanan, S. and Saifudeen, N. 1996. Effect of VAM inoculation, soil sterilization and phosphorus application on the growth and nutrient removal by cassava. Tropical tuber crops: problems, prospects and future strategies, pp 227-232.

Niang, A., Styger, E., Gahamanyi, A., Hoekstra, D., and Coe, R.1998. Fodder-quality improvement through contour planting of legume-shrub/grass mixtures, in croplands of Rwanda highlands. Agroforest. Sys., 39: 263-274.

Njoka-Njiru, E.N., Njarui, M.G., Abdulrazak, S.A., and Mureithi, J.G. 2006. Effect of intercropping herbaceous legumes with napier grass on dry matter yield and nutritive value of the feedstuffs in semi-arid region of Eastern Kenya. Agricultura Tropica et Subtropica, 39 (4): 260-272.

Njoku, D.N. and Muoneke, C.O. 2008. Effect of cowpea planting density on growth yield and productivity of component crops in cowpea - cassava intercropping system. Agro-Science, 7(2):106-113.

Obigbesan, G.P. 1973. The influence of potash nutrition on the yield and chemical composition of some tropical root and tuber crops. International Potash Institute Coloquinon, Tenth, Abidyan Ivory Coast, pp 439-451.

Okoli, O.O. 1996. Effect of planting dates and growth habits of cassava and cowpea on their yield and compatibility. Tropic. Agric., 73 (3): 169-174.

Okon, I.E. and Osonubi, O. 2005. Effects of arbuscular mycorrhizal fungus and pruning regimes of woody legumes on the tuber yield of alley-cropped cassava. Global J. Pure and Applied Sci., 11(1): 9-12.

Olasantan, F.O., Ezumah, H.C., and Lucas, E.O. 1995. Effects of intercropping with maize on the micro environment, growth and yield of cassava. Agriculture Ecosystems and Environment, 57(2/3): 49-158

Olasantan, F.O., Ezumah, H.C., and Lucas, E.O. 1997. Response of cassava and maize to fertilizer application and a comparison of the factors affecting their growth during intercropping. Nutrient cycling in Agro ecosystems, 46: 215-223.

Osonubi, O., Atayese, M.O., and Mulongoy, K. 1995. The effect of vesicular-arbuscular mycorrhizal inoculation on nutrient uptake and yield of alley-cropped cassava in a degraded Alfisol of southwestern Nigeria. Biol. Fertility Soils, 20 (1): 70-76.

Osundare, B., and Agboola, A.A. 2003. Effects of different companion crops on the performance of cassava. Moor J. Agric. Res., 4(1): 50-53.

Oyetunji, O.J., Osonubi, O., and Ekanayake, I.J. 2003. The vegetative growth and yield response of two cassava clones to *Glomus fasciculatum* inoculation in semi-controlled conditions. Afr. J. Root Tuber Crops, 5(2): 52-55.

Oyetunji, O.J. and Osonubi, O. 2007. Assessment of influence of alley cropping system and arbuscular mycorrhizal (AM) fungi on cassava productivity in derived savanna zone of Nigeria. World J. Agric. Sci., 3(4): 489-495.

Pal, T.K., Ramanathan, S., and Anantharaman, M. 1992. Cost of cultivation of cassava in Kerala. J. Root Crops, 18(1): 22-25.

Panse, V.G. and Sukhatme, P.V. 1995. Statistical method for Agricultural workers. Third edition. Indian Council of Agricultural Research, New Delhi, p.381.

*Polthanee, A., Wanapat, S., and Mangprom, P. 1998. Row arrangement of peanut in cassava-peanut intercropping: II. Nutrient removal and nutrient balance in soil. Khon Kaen Agric. J., 26 (3): 125-131.

Polthanee, A., and Kotchasatit, A. 1999. Growth, yield and nutrient content of cassava and mungbean grown under intercropping. Pakistan J. Biol. Sci., 2(3): 871-876.

Polthanee, A., Wanapat, S., Wanapat, M., and Wachirapokorn, C. 2007. Cassava-legumes inter-cropping: A potential food - feed system for dairy farmers http://www.mekarn.org/procKK/polt.htm.

Potty, V.P. 1990. Response of cassava (*Manihot esculenta* Crantz.) to VA Mycorrhizal inoculation in acid laterite soil. J. Root Crops, 16(2):132-139.

Prabhakar, M. and Nair, G. M. 1992. Effect of some agronomic practices on growth and productivity of cassava- groundnut intercropping system. J. Root Crops, 18(1): 26-31.

Prabhakar, M., Nair, G.M., and Ghosh, S.P. 1996. Intercropping legumes with cassava. Agric. International, 47(11): 26-128.

Prasad, K. and Srivastava, R.C. 1991. Pigeon pea (*Cajanus cajan*) and Soybean (*Glycine max*) intercropping system under rainfed situation. Indian J. Agric. Sci., 61(4): 243-246.

Ramanathan, S. and Anantharaman, M. 2003. www. Ciat. Cgiar. Org/ asia/ casava / workshop.

Reddy, V.C. and Naik, G. 1999. Effect of intercrops of annual forage legumes and nitrogen levels on the performance of hybrid napier. Leg. Res., 22 (4): 275-276.

Reddy, V.C., Praveen, B., Murthy, K.N.K., and Shekara, B.G. 2004. Grass and legume intercropping for sustainable fodder production. Environ. Ecol., 22 (4): 874-876.

*Ricaurte, J., Qi ZhiPing Filipe, D., Rao, I., and Amezquita, E. 2000. Root distribution, nutrient absorption and soils erosion in forage and crops systems in Cauca hillsides. Colombia .Suelos Ecuatoriales, 30(2):157-162.

Salami, A.O. and Osonubi, O. 2006.Growth and yield of maize and cassava cultivars as affected by mycorrhizal inoculation and alley cropping regime. J. Agric. Sci. Belgrade, 51(2):123-132.

Savithri, K.E., and Alexander, D. 1995. Performance of cowpea varieties in cassava-cowpea intercropping system. Leg. Res., 18(1): 59-60.

Sheela, K.R. 1981. Nutritional requirement of tapioca based intercropping system. M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur.187p.

Sheela, K.R. and Mohammed Kunju. 1990. Fertilizer requirement and economics of cassava based intercropping system. J. Root Crops, 16(1): 53-55.

Sheela, K.R., Devi, L.G., Pillai, G.R., Kumar, A.S.A., and Swadija, O.K. 1996. Planting geometry and nutrient management studies in cassava - fodder cowpea intercropping system. J. Root Crops, 22(1):18-22.

Streck, A.S. N.A., Storck, L., Buriol, G.A., Zanon, A.J., Pinheiro, D. G., and Kraulich, B. 2009. Plant spacing in monocropping and intercropping of cassava and maize: growth, development, and yield. Bragantia, 68(1): 155-167.

*Silva, S., da Siqueira, J.O., and Soares, C.R.F.S. 2006. Mycorrhizal fungi influence on brachiaria grass growth and heavy metal extraction in a contaminated soil. Pesquisa Agropecuaria Brasileira, 41(12): 1749-1757.

Simpson, J.E., Adair, C.R., Kohler, G.D., Dawson, E.N., Debald, H.A., Kester, E.B., and Klick, J.T. 1965. Quality evaluation of foreign domestic rices. Technical Bullettin. No.1331.Series.USDA.1-86p.

Singh, H.P. 1990. Response of dual inoculation with Brady Rhizobium and VA mycorrhizae or phosphate solubilisers on soybean in mollisol. (In) Trends in mycorrhizal research. Proceedings of the national conference on mycorrhizae held at HAU, India., pp120-121.

Singh, R., Naveen K., and Rana, N.S. 2000.Response of rainfed guinea grass (*Panicum maximum*) to bio-fertilizers inoculation and nitrogen. Indian J. Agron., 45(1): 205-209.

Siqueira, J.O., Rocham, W.F., Jr. Oliveira, E., and Colozii-Filho, A. 1990. The relationship between vesicular-arbuscular mycorrhiza and lime: associated effects on the growth and nutrition of brachiaria grass (*Brachiaria decumbens*). Biol. Fertility Soils, 10(1): 65-71.

Sivaprasad, P., Inasi, K.A., and Kunju, U.M. 1989. Response of cassava and sweet potato intercropped in coconut garden to VA mycorrhizal inoculation. J. Root Crops, 15(1): 49-53.

Sivaprasad, P., Sulochana, K.K., and Nair, S.K. 1990. Comparative efficiency of different VA mycorrhizal fungi on cassava (*Manihot esculenta,* Crantz). J. Root Crops, 16(1): 39-40.

Sivaprasad, P., Narayanan, S., and Sulochana, K. 1991. Relative efficiency of VA mycorrhizae for soil nutrient uptake in cassava (*Manihot esculenta* Crantz.). J. Root Crops, ISRC.Nat.Sym.Special:97-99.

*Souza, R.F., de Pinto, J.C., Siqueira, J.O., and Rezende, V.F. 1999a. Effects of mycorrhizae and phosphorus fertilizer on growth of *Brachiaria brizantha* and *Stylosanthes guianensis* on soil of low fertility. 1.Dry matter and crude protein yields. Pasturas Tropicales, 21(3): 24-30.

*Souza, R.F., de Pinto, J.C., Siqueira, J.O., and Rezende, V.F. 1999b. Effects of mycorrhizae and phosphorus fertilizer on growth of *Brachiaria brizantha* and *Stylosanthes guianensis* on soil of low fertility. 2. Mineral uptake. Pasturas Tropicales, 21(3): 24-30.

Sreedurga, N. 1993. Effect of microbial inoculants in *Stylosanthus guinaensis* cv *schofield* for herbage production M.Sc. (Ag) thesis. Kerala Agricultural University, Thrissur, 92 p.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available Nitrogen in soils. Curr. Sci., 29: 259-260.

Thamburaj, S. 1991. Research accomplishments in tapioca at Tamil Nadu Agricultural University. In: Green Book on tapioca. Ed. Ashok Kumar Gupta, pp17.

Tholkappian, P., Sivasaravanan, A., and Sundaram. 2000. Effect of phosphorus levels on the mycorrhizal colonization, growth, yield, and nutrient uptake of cassava (*Manihot esculenta* Crantz.) in alluvial soils of coastal Tamil Nadu. Mycorrhiza News., 11(4): 15-17.

Thomas, G.C. 2003. Forage production in the tropics. Kalyani publishers. New Delhi, 259p.

Tripathi, R.K., Pradhan, L., and Rath, B.S. 1997. Performance of maize (*Zea mays*) and cowpea (*Vigna unguiculata)* forage intercropping system. Indian J. Agron., 42 (1): 38-41.

Udoh, A.J. and Ndaeyo, N.U. 2000. Crop productivity and land use efficiency in cassava - maize system as influenced by cowpea and melon populations. Tropic. Agric., 77(3): 150-155.

Ullah, M.A., Tariq, A.N., and Razzaq, A. 2007. Effect of rice bean (*Vigna umbellata*) inter-cropping on the yield of perennial grass, *Panicum maximum CV. Gaton* under rain-fed conditions. J. Agriculture Social Sciences, 3(2): 70–72.

Uma, M.R. and Rao, V.S. 1994. Effects of inoculation with VAM fungi, phosphate solubilising fungus and phosphate amendments on black gram and green gram. Indian J. Microbiology, 34 (4): 313-316.

*Weinchang, H. 2007. Effect of mycorrhizal fungi, actinomycetes, and *Bacillus subtilis* on growth of pangola grass and napier grass. J. Taiwan Liv. Res., 40 (4): 203-211.

* Originals not seen

Appendix

Weather data during the crop period (June 2009 to December 2009)

Period	Maximum temperature (ºC)	Minimum temperature (ºC)	Rainfall (mm)	Relative Humidity (%)	Evaporation (mm)
June	31.0	24.0	174.0	85.7	2.9
July	30.1	24.0	190.6	87.1	2.8
August	30.2	24.1	74.9	84.6	3.3
September	29.6	24.2	114.2	88.0	3.5
October	30.4	24.2	100.9	87.3	3.5
November	29.5	23.8	485.7	87.0	2.9
December	30.7	23.7	51.6	88.1	3.3

Alley cropping in cassava (*Manihot esculenta* Crantz.) for food –fodder security

GAYATHRI, P.

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

Master of Science in Agriculture

`

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2010

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695522

ABSTRACT

A field experiment was conducted to asses the bio and economic suitability of raising fodder grasses and legumes in the alleys of cassava for food - fodder production and to study the response of the system to AMF application at the Instructional Farm attached to the College of Agriculture, Vellayani during 2009. The experiment with fourteen treatments was laid out in Randomized Block Design with three replications. Cassava was planted in paired rows (120/60 cm x 90 cm) with fodder grasses and fodder cowpea and combination of fodder grass and fodder cowpea in the inter spaces with and without AMF.

Highest tuber yield was obtained from sole cassava followed by cassava + fodder cowpea and cassava + palisade grass + fodder cowpea. The yield attributes of cassava were not influenced by alley cropping indicating the suitability of alley cropping in paired row planted cassava. The total dry fodder yield and crude protein yield of the system were highest in cassava + palisade grass + fodder cowpea combinations.

All treatments recorded a total LER value more than one. The fodder crops were found to be more aggressive and with high competitive ability than cassava. Highest cassava equivalent yield of 22.95 t ha^{-1} was recorded by sole cassava on par with cassava + fodder cowpea + AMF with a yield of 20.01 t ha^{-1} and cassava + palisade grass +fodder cowpea (19.78 t ha^{-1}) .

Nutrient uptake by cassava was not influenced by the presence of fodder crops or AMF application. Application of AMF also had no influence on the yield and net returns of the system.

Highest net income, cassava equivalent income and B: C ratios were obtained from sole crop of cassava followed by cassava + palisade grass + fodder

cowpea. Application of AMF had no influence on the biological, economic and land use efficiency of the system.

Hence it can be concluded that to achieve the objective to find out a cassava based fodder production system for food – fodder security, alley cropping in cassava cv. Vellayani Hraswa of duration six months with two rows of palisade grass inter-planted with one row of fodder cowpea is the most efficient with respect to biological productivity (cassava equivalent yield of 19.78 t ha^{-1}), quality of feed (crude protein yield of 0.59 t ha^{-1}), economic returns (cassava equivalent income of Rs. 98936 ha^{-1}) and land use efficiency (land equivalent ratio of 1.70).