BIOMASS PRODUCTIVITY OF A FORAGE CROP BASED CROPPING SYSTEM INVOLVING C_3 AND C_4 PLANTS

BY

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THESIS

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1988

DECLARATION

I hereby declare that this thesis entitled "Biomass productivity of a forage crop based cropping systems involving C_3 and C_4 plants" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Biomass productivity of a forage crop based cropping system involving C_3 and C_4 plants" is a record of research work done independently by Shri. M. JAYAKUMAR, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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(contd..2.)

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(M.JAYAKUMAR)

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INTRODUCTION

INTRODUCTION

The dry roughage requirement for the 3.45 million livestock in Kerala is estimated to be 60.00 lakh tonnes, but, the production at present is only 33.50 lakh tonnes (Anon., 1984). This evidently highlights the need to evolve new technology and better management practices for increased fodder production. Fodder crops like guinea grass, maize, cowpea which are popular in the State differ in their ability to fix carbondioxide, in their productivity and quality. This is mainly because these fodder crops follow different photosynthetic pathways. Guinea grass and maize, two important fodder crops of the country carry out photosynthesis by following C_4 - dicarboxylic acid pathway (Gibbs and Latzko 1979) and as such their growth rate is also high. The crop growth rate of maize is reported to be 50 - 54 $g/m^2/d$ (Evans. 1976). Leguminous fodder crops like cowpea carry out photosynthesis following a C_3 - photosynthetic pathway (Mott., 1981). They are photorespiring and slow growing and thus their biomass productivity is also less compared to C_4 plant. The crop growth rate of legumes is reported to be 30 - 39 $g/m^2/d$ which is far less than C_4 plants (Carlleopard and Paul 1985).

Fodder cultivation through intercropping is being considered as an excellent strategy to boost the fodder production of the country. Paired row planting is one of the ways of accommodating full population of a base crop and creating interspace wide enough to accommodate one or more rows of intercrops (Palaniappan, 1985).

Maintenance of high initial population of intercrops followed by sequential thinning is thought to be a better strategy to increase the energy harvesting from a cropping system and thus the total biomass production from a forage crop based cropping system. Intercrops differ in their ability to perform under different planting geometry of base crop (Keswani and Ndunguru, 1980).

Much effort have been made by scientists in the past to evaluate the biomass productivity of fodder crops in solid planting as well as in intercropping situations. On the contrary little effort have been made to evaluate the total biomass productivity of a forage crop based croppin system involving sequential thinning of intercrops grown in the interspace of the base crop with different planting geometry. Similarly information on the total biomass productivity of a forage crop based cropping system with different row arrangement and intercrops involving C_3 and C_4 plants, is also meagre.

Under the circumstances an experiment was conducted in the Instructional farm attached to the College of Agriculture, Vellayani with the following objectives.

1. To compare the performance of guinea grass under different planting geometry.
2. To study the total biomass productivity of C_4 grass based cropping system through intercropping with C_3 and C_4 plants.
3. To evaluate the suitability of fodder maize (C_4) and fodder cowpea (C_3) as intercrops in a perennial grass.
4. To study the feasibility of maintenance of higher initial population followed by sequential thinning on the total biomass productivity of a grass based cropping system.
5. To study the economics of production of a forage crop based cropping system involving C_3 and C_4 plants.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Scientific efforts have been made in the past to evaluate the production potential of fodder crops like guinea grass, maize and cowpea under different agro-climatic situations. A brief review of work done on these crops to evaluate their production potential, nutrient removal and fodder quality when grown in sole and intercropping situations is presented in this section.

1. Performance of guinea grass in sole cropping

Guinea grass when grown at the College of Agriculture, Vellayani as a sole crop, could produce 8.37 t/ha of green fodder and 1.52 t/ha of dry fodder from a single cut (Krishnaraj, 1976). Chandini and Raghavan Pillai (1980) reported that guinea grass produced 8.74, 11.91 and 5.16 t/ha of green fodder from the 1st,2nd and 3rd cut respectively. The corresponding dry fodder yields were 1.78, 1.92 and 1.1 t/ha. It was also reported that guinea grass variety Makuenii when grown in the same set up could produce as much as 46 tonnes of fresh fodder and 15 t/ha of dry fodder in 5 cuts (Anon., 1983). Raghavan Pillai (1986) reported that guinea grass produced 7.55 t/ha of dry fodder from three cuts.

The leaf:stem ratio of guinea grass was reported to range from 2.35 to 2.59 according to Chandini (1980).

Gomide et al (1969) reported that crude protein content of guinea grass decreased with advancement of age. According to Krishnaraj (1976) guinea grass yielding 8.3 t of fresh fodder yield could produce 195.5 kg/ha of crude protein. In a similar study Chandini and Raghavan Pillai (1980) obtained 277.5 kg/ha of crude protein from a crop yielding 25.8 t/ha of fresh fodder in 3 cuts.

A crop yielding 7.55 t of dry fodder per hectare removed 100 kg nitrogen, 17 kg phosphorus and 112 kg potassium from the soil (Raghavan Pillai, 1986).

When guinea grass was grown for one year, a rise in total nitrogen of soil from 1086 kg/ha to 1216 kg/ha was noticed by Krishnaraj (1976).

Similarly improvement in Nitrogen content of soil due to continuous growing of forage grass was reported by White et al (1976) in Australia.

2. Performance of maize in sole cropping

Tiwana and Puri (1976) while comparing different fodder varieties found that variety African tall produced highest yield of 24.1 t/ha of green fodder. Fodder production with fodder maize increased with increase in plant density (Leshem and Wermke, 1981). But the same variety African tall at Vellayani could produce only 10.2 t of green fodder and 2.5 t/ha of dry fodder (Anon.,1985). Same variety produced 22.26 t/ha at silk stage in Maharashtra according to Sawant and Khanvilkar (1985).

Leaf: stem ratio of fodder maize varies with age of the crop (Mercy, 1981). According to her leaf:stem ratios of fodder maize were 14.1, 3.9 and 2.0 respectively at 20th, 40th days after sowing and at harvest. A maize crop yielding 20.2 t/ha of fodder produced 812 kg of crude protein (Mercy, 1981).

Glogov (1969) and Mercy (1981) reported that nitrogen, phosphorus and potassium contents of the plant decreased with age of the crop. Khan and Zende (1976) reported that phosphorus uptake by fodder maize increased considerably with the age of the crop. Nitrogen, phosphorus and potassium uptake in maize were 65.9, 6.1 and 47.1 kg/ha respectively from a crop yielding 20.2 t/ha of fresh fodder (Mercy, 1981). She also reported that the total nitrogen content of soil decreased considerably by growing a fodder crop of maize though not significantly.

3. Performance of cowpea in sole cropping

Green fodder yield of fodder cowpea varies with varieties and ranges from 11.58 to 23.75 t/ha and the corresponding dry matter yield ranges from 1.82 to 5.03 t/ha (Nawargaonkar *et al* 1980). According to Ramanagowda (1981) Cowpea variety C-152 produced 32.42 t/ha of fresh fodder (7.3 t/ha of dry fodder with protein content of 18.54%).

The crude protein content of fodder cowpea was reported to be 17.4% (Kelwani and Kumar 1969). Weather (1969) reported that crude protein of cowpea varied with varieties and it ranged from 16.3 to 26.1%. Ramanagowda (1981) reported that fodder cowpea yielding 20.5 t/ha of fresh fodder contained 902.9 kg/ha of protein and has removed 140.03 kg/ha of nitrogen, 8.766 kg/ha of phosphorus and 151.5 kg/ha of potassium from soil.

The post harvest soil fertility in terms of organic carbon (total nitrogen) was improved due to growing of fodder cowpea (Nair *et al* 1973 and Ramanagowda,1981).

4. Effect of planting geometry on fodder crops

Information on the effect of planting geometry on fodder crops could not be traced in literature. Effect of planting geometry of grain crops revealed tnat change in planting geometry did not cause any difference in grain yield of ragi (Anon., 1974) and grain yield of sorghum (Gangaprasad Rao, 1975 and Singh, 1976).

Paired row planting of crop facilitates growing of intercrops very much since the space available in between pairs is more than that available in solid stand (Palaniappan, 1983).

5. Effect of intercropping on fodder crops

5.1 Freshfodder yield

Intercropping of Lucern (Medicago sativa) with napier grass (Pennisetum purpureum) reduced the fresh fodder yield of napier grass compared to a solo crop of napier (Villegas, 1956). According to Strange (1961), intercropping of legume with fodder maize resulted in the decline of maize yield, but total fodder yield from maize + legume intercropping system was higher. Similar beneficial effect of maize + legume intercropping on total fodder yield was reported by Dayal et al (1967) and Muthuswamy et al (1980).

Intercropping of lucern in guinea grass increased fresh fodder yield by 36% (Cameron, 1969). Similar beneficial effects of guinea grass + lucern over guinea grass sole crop were reported by Whitney and Kanehiro (1967) from Australia and by Grof and Harding (1970) from Queensland.

Experiments conducted at the College of Agriculture, Vellayani (Anon., 1975) revealed that intercropping stylosanthes in guinea grass increased the total fodder yield compared to guinea grass sole cropping. Guinea grass + stylosanthes intercropping produced a total fresh fodder yield 22.1 t/ha while guinea grass sole cropping resulted in a production of 19.7 t/ha of fresh fodder yield.

Experiments conducted at the College of Agriculture, Vellayani from 1971 to 1978 (Anon., 1978) conclusively proved the superiority of guinea grass + cowpea intercropping in terms of fresh fodder yield compared to sole cropping of guinea grass and cowpea. Similar beneficial effects on total fodder production was reported by Chandini and Raghavan Pillai (1980) in guinea grass + legume intercropping and Shanmugasundaram (1980) in napier grass + lucern intercropping.

5.2. Dry fodder yield

Teakle (1954) reported that growing a single row lucern in between rows of green panic (<u>Panicum maximum</u> var. <u>trichoglume</u>) resulted in the production of 33 t/ha of dry matter compared to 18.4 t/ha in sole crop of green panic.

Similar increase in total dry fodder yield due to legume intercropping was reported by Chauhan et al (1967) in anjan grass and Patel et al (1968) in guinea grass.

Krishnaraj (1976) reported that guinea grass + cowpea intercropping produced total dry fodder yield of 10.8 t/ha against 8.3 t/ha in guinea grass sole cropping in 8 cuts. Similar increase in dry matter yield due to guinea grass + legume intercropping was reported by Chandini and Raghavan Pillai (1980) and Raghavan Pillai (1986).

The beneficial effects of anjan grass + cowpea intercropping over anjan grass sole cropping in terms of dry fodder yield was reported by Chauhan et al 1981. They further reported that the yields of anjan grass in subsequent cuts were higher in cowpea intercropped plots compared to the yield obtained from pure crop of anjan grass.

5.3 Leaf-stem ratio

Intercropping cowpea with guinea grass did not change the leaf-stem ratio of the fodder (Krishnaraj, 1976 and Chandini and Raghavan Pillai, 1980). But Raghavan Pillai (1986) reported that guinea grass + stylosanthes intercropping increased the leaf-stem ratio from 1.93 to 2.03. Mott (1981) reported that C_3 plants have higher leaf-stem ratio than C_4 plants.

5.4 Protein yield

The protein content of the fodder obtained from green panic + lucern intercropping system was higher than that obtained from pure crop of green panic (Panicum maximum var. trichoglume) (Teakle, 1954). Similarly, protein yield of fodder obtained from maize + soybean intercropping system was higher than that obtained from sole crop of maize (Ipeakozhiyan and Nikitonko, 1959). Patel et al (1968) reported that protein content of fodder obtained from guinea grass + lucern intercropping was higher than that obtained from guinea grass sole cropping.

Krishnaraj (1976) reported that the protein yield from the grass-legume association depends on the type of legume involved. He has estimated the protein yield from guinea grass + cowpea, guinea grass + stylosanthes and guinea grass sole crop ans reported that protein yield from these three systems were respectively 1400, 1061 and 934 kg/ha. Similar beneficial effects of grass-legume association over sole cropping in protein production were reported by Chandini and Raghavan Pillai (1980) and Chandini et al (1982). Superiority of maize + legume inter-cropping over maize sole cropping in protein yield was reported by Muthuswamy et al (1980).

5.5 Nutrient removal

Patel *et al* (1968) reported that nitrogen and phosphorus contents of fodder obtained from guinea grass + lucern intercropping was higher than that from guinea grass sole crop. Nitrogen content of fodder obtained from setaria desmodium intercropping was 10-15 per cent higher than that from setaria sole crop (Thairu, 1972). The nitrogen and phosphorus contents of fodder obtained from guinea grass + stylosanthes intercropping were higher than that from guineagrass sole crops. Chauhan *et al.*(1981) observed increased nitrogen uptake in intercropping system involving anjan grass + cowpea compared to anjan grass sole crop. According to Raghavan Pillai (1986) uptake of nitrogen, phosphorus and potassium from guinea grass + stylosanthes was more than that from guinea grass sole cropping.

5.6 Soil fertility

Molsted (1954) reported that intercropping legume in maize has increased the organic matter content of the soil. Similar increase in organic matter status of soil by grass-legume intercropping was reported by Mandal (1954); Dayal *et al* (1967) and Singh and Chatterjee (1968). Improvement in soil fertility in terms of soil organic carbon and total nitrogen due to grass + legume intercropping has been reported by Singh and Singh (1967), Sherman (1977), Gillard (1977), Chandini and Raghavan Pillai (1980) and Raghavan Pillai (1986).

5.7 Economics

Ibrahim *et al* (1969) reported that intercropping of cowpea with napier grass was more profitable than napier sole cropping. Similarly maize + soybean intercropping was found to be more economical than maize sole crop (Jagannathan, 1972). The profits of Rs.4,820/-ha in guinea grass + cowpea intercropping over guinea grass sole crop (Krishnaraj *et al* 1979) and the profit of Rs.4,478/-ha in guinea grass + stylosanthes intercropping over guinea grass sole crop (Chandini and Raghavan Pillai, 1980) were reported from the College of Agriculture, Vellayani.

The review of literature on the performance of fodder crops presented in the foregoing sections clearly reveals that the fodder crops guinea grass, maize and cowpea perform well in the State of Kerala. From the review presented above, guinea grass + legume intercropping was better in terms of fodder production, protein yield, post harvest soil fertility and net income compared to sole cropping of grass.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken with a view to find out the suitability of fodder maize and fodder cowpea as intercrops in a guinea grass based cropping system for increasing biomass productivity. The materials used and methods adopted are detailed below.

Experimental site

The experiment was conducted at the Instructional farm attached to the College of Agriculture, Vellayani.

Soil

The soil of experimental site is of red loam coming under the order Alfisol. Data on the physico-chemical properties of soil are given in Table 1.

Season and climate

The experiment was started in the month of June and continued upto November 1987. The meteorological data for the above period are presented in Fig.1 and Appendix I.

Cropping history of the field

The experimental area was occupied by a bulk crop of Elephant footyam during the previous season.

Table 1. Physico-chemical properties of soil before the experiment

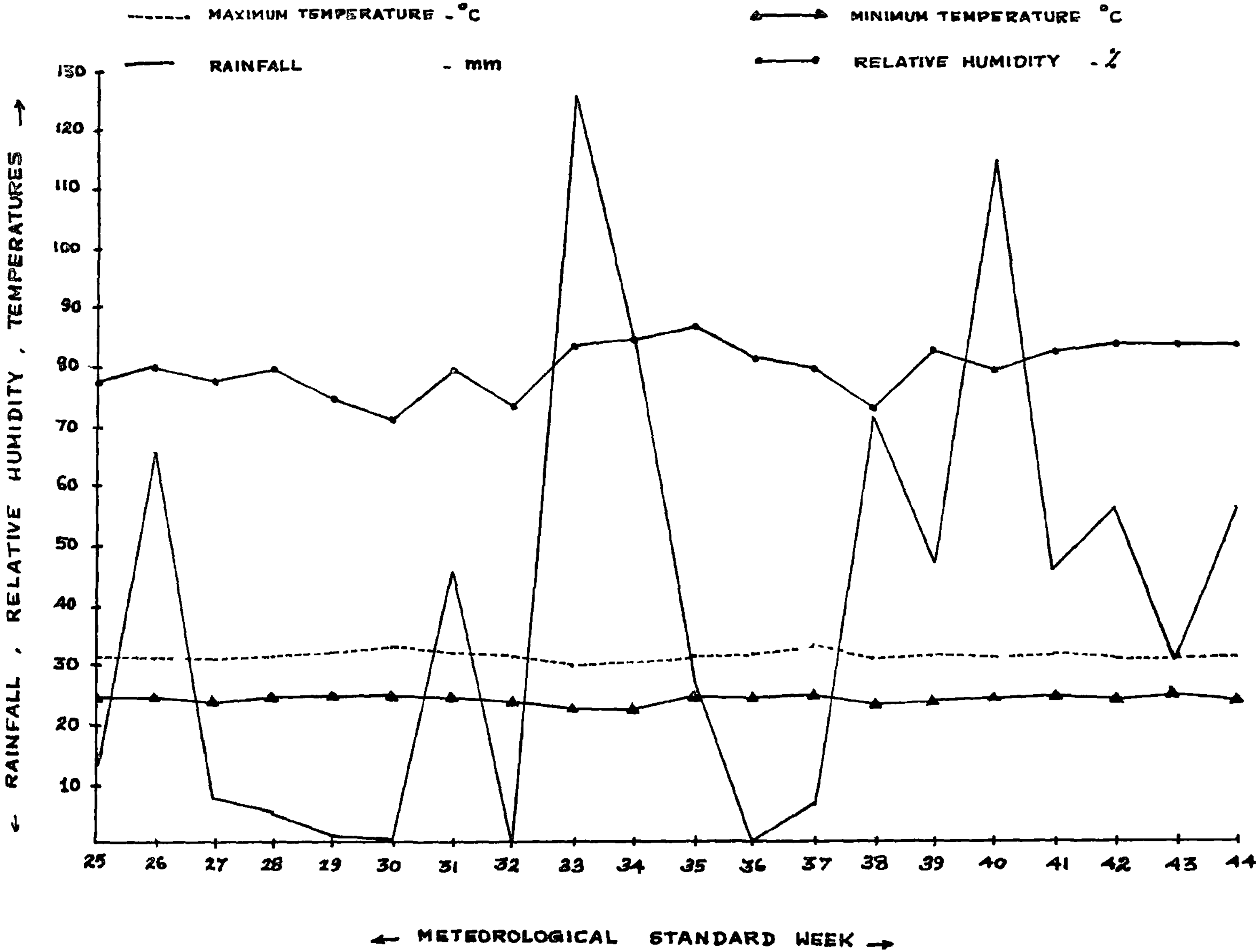
Chemical composition

Constituents	Content in soil	Rating (Anon.1985)	Methods used
Total Nitrogen	1334 kg/ha	-	Modified - Microkjeldahl Method
Available Nitrogen	160 "	Low	Alkaline permagnate method
Available P_2O_5	35.1 "	Medium	Bray's colorimeter method
Available K_2O	40.14 "	Low	Ammonium acetate method
Organic carbon	0.729%	High	Walkley and Black's Rapid titration method
pH	5.1	Acidic	1: 2 soil solution ratio using pH meter

Mechanical composition

Coarse sand (%)	13.7
Fine sand (%)	33.4
Silt (%)	28.0
Clay (%)	24.7
Textural class -	Loam

FIG I WEATHER CONDITIONS DURING THE CROPPING PERIOD



<u>Crops and varieties</u>

1. Guinea grass (<u>Panicum maximum</u> J.)

This is the principal base crop of the experiment. It is drought resistant, perennial and well relished by all categories of livestock. Average green fodder production in Kerala is 30-49 t/ha (Anon., 1983). Slips were obtained from the District Livestock Farm, Kodappanakunnu. The variety used was Makuenii which is popular throughout the State (Anon., 1980).

2. Cowpea (<u>Vigna unguiculata</u> S)

It is a good fodder yielding legume proved to be suitable for cultivation in Kerala (Gopimony <u>et al</u> 1982). New Era, a north Rhodesian variety of cowpea was used for the experiment. Average fodder yield ranged from 20-30 t/ha (Ramanagowda, 1981). Seeds were obtained from the District Livestock Farm, Kodappanakunnu. Seeds were tested for viability and were found to give 92 per cent germination. Cowpea was grown as intercrop in the interrow space of guinea grass.

3. Maize (<u>Zea mays</u> Linn.)

It is a good silage crop, highly nutritious and palatable with an average yield of 30-35 t/ha. It can be fed to cattle at any stage of growth and is well relished by livestock. African tall a high yielding fodder maize variety which is recommended for fodder cultivation in the State (Anon., 1985) has been chosen for the study. The seeds had 96 per cent germination.

Experimental details

The experiment consisted of 12 treatments with 3 replications. The details of the treatments are given below. For the convenience in presentation the crop guinea grass is abbreviated as GG in the treatment details given below.

T_1 - Guinea grass sole crop normal planting of 60 x 30 cm

T_2 - Guinea grass sole crop paired row planting of 30x30/9

T_3 - GG at 60 x 30 cm + 2 rows of maize and no thinning.

T_4 - GG at 30 x 30/90 cm + 4 rows of maize and no thinning

T_5 - GG at 30 x 30/90 cm + 6 rows of maize initially and reduced to 4 at 50 DAS.

T_6 - GG at 30 x 30/90 cm + 8 rows of maize initially and reduced to 6 rows at 30 DAS and further reduced to 4 rows at 50 DAS.

T_7 - GG at 60 x 30cm + 3 rows of cowpea and no thinning.

T_8 - GG at 30 x 30/90 cm + 6 rows of cowpea and no thinnin

T_9 - GG at 30 x 30/90 cm + 9 rows of cowpea initially and reduced to 6 at 30 DAS.

T_{10} - GG at 30 x 30/90 cm + 12 rows of cowpea initially and reduced to 9 rows at 30 DAS and further reduced to 6 rows at 50 DAS.

T_{11} - Maize sole crop at 30 x 15 cm

T_{12} - Cowpea sole crop at 20 x 10 cm

The population of guinea grass was kept constant in treatments T_1 to T_{10}. The intra row spacing of maize was also kept constant (15 cm) in all the treatments involving maize. Similarly the intra row spacing of cowpea was kept as 10 cm uniformly in all the treatments involving cowpea.

Design and Layout

Number of replications	-	3
Number of treatments	-	12
Total number of plots	-	36

Plot size

Gross plot size	- 7.2 x 3.0 m
Net plot size	- 6 x 2.4 m
Border row	- One row of plants was left as border row all around the plot.

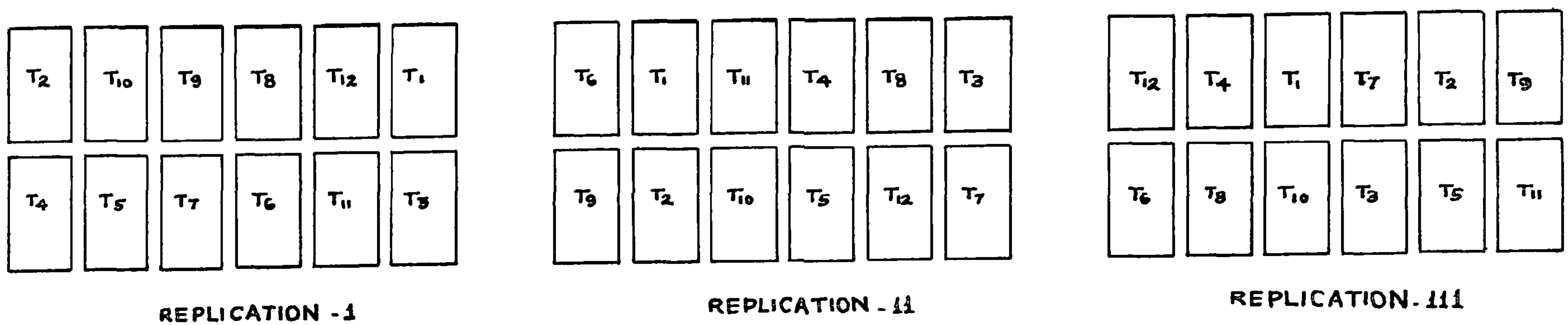
Details of cultivation

The experimental area was dug twice, stubbles were removed, clods were crushed and levelling was done before laying the beds of size 7.2 x 3.0 m.

Manuring

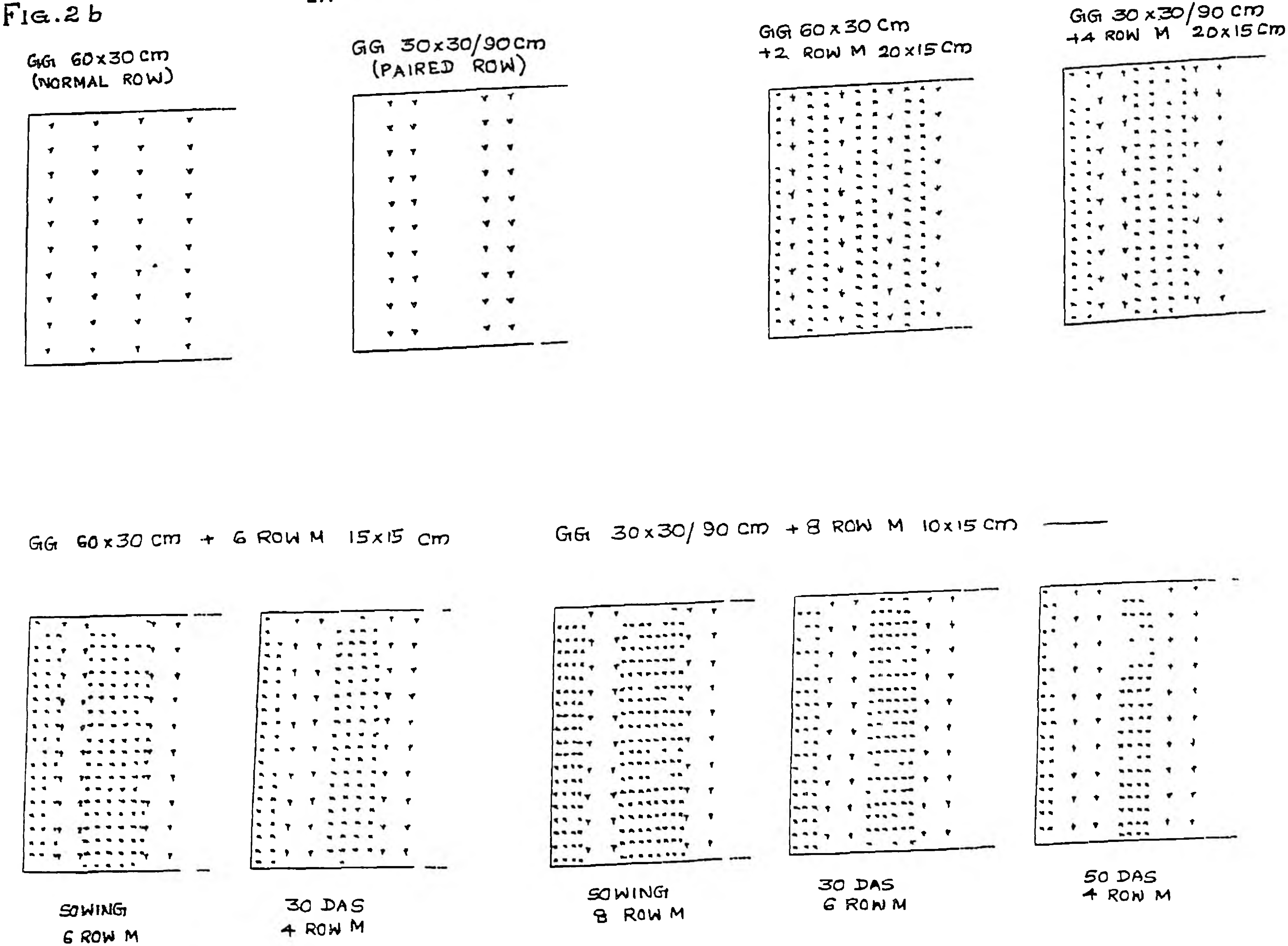
A uniform basal dose of 10 t/ha of farm yard manure (containing 0.46% N, 0.30% P_2O_5 and 0.27% K_2O on dry weight basis) was applied and well incorporated into the beds during the final preparation of the field.

FIG 2 LAYOUT PLAN - RANDAMISED BLOCK DESIGN



LAY OUT PLAN OF TREATMENTS

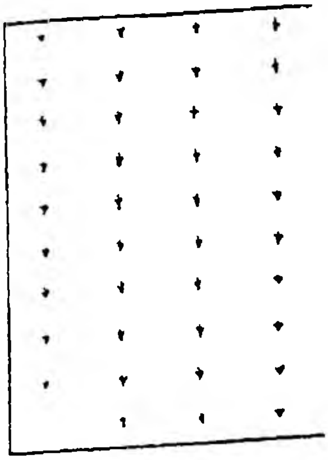
FIG. 2 b



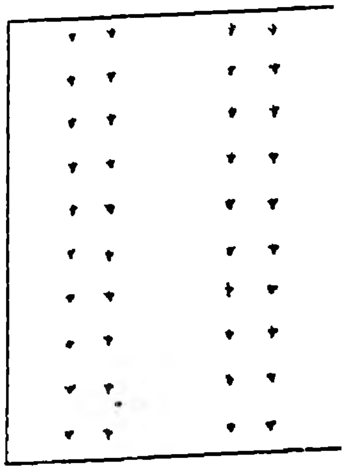
✶ GG - GUINEA GRASS. , × M - MAIZE, CP COWPEA

CONTD

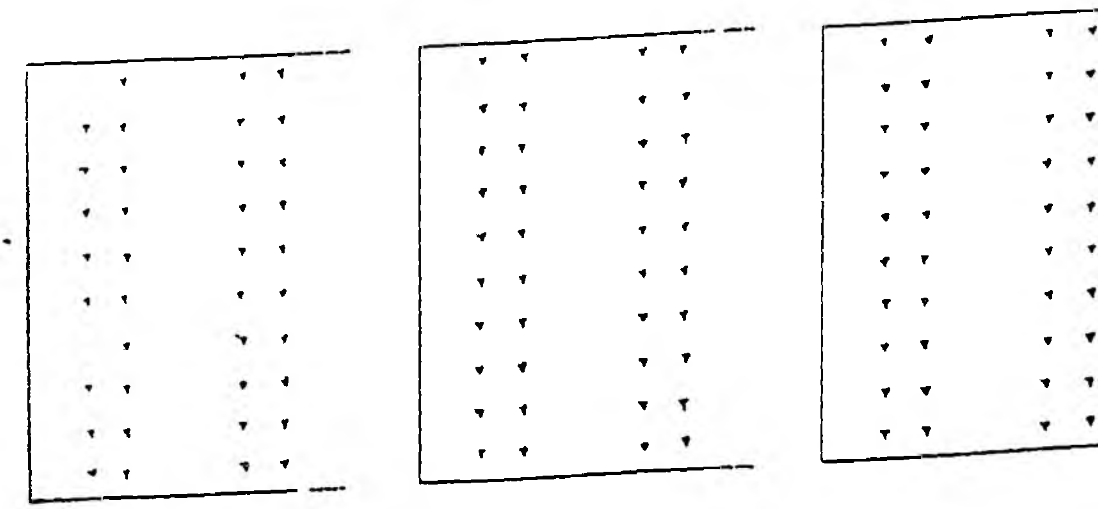
GG 60x30cm +
3 ROW CP 20x10cm



GG 30x30/90cm +
6 ROW CP 15x10cm



GG 30x30/90cm +12 ROW CP 7 5 x 10 cm

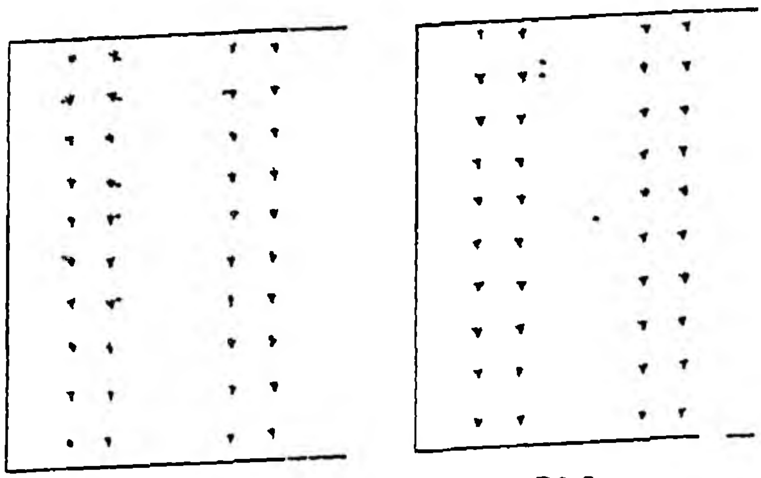


SOWING
12 ROW CP

30 DAS
9 ROW CP

50 DAS
6 ROW CP

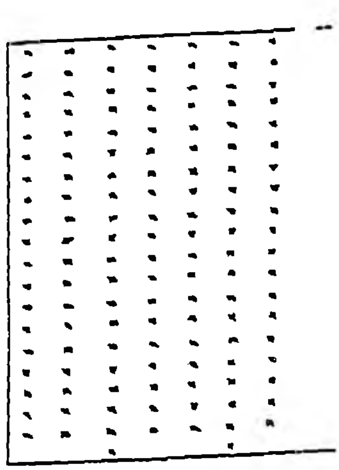
GG 30 x 30/90 cm + 9 ROW CP 10 x 10 cm



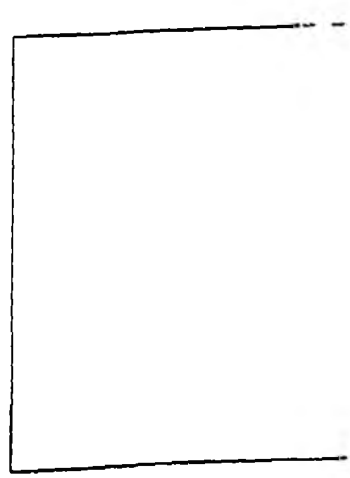
SOWING
9 ROW CP

30 DAS
6 ROW CP

M 30 x 15 cm



CP 20 x 10 cm



GG - GUINEA GRASS M MAIZE CP COWPEA

Fertilizer application

A uniform dose of N, P_2O_5 and K_2O recommended to guinea grass (200-50-50 kg/ha) was given to all the plots. The N, P_2O_5 and K_2O contents of the fertilizers used were as follows:-

Ammonium sulphate	- 20.5% (N)
Superphosphate single	- 16% (P_2O_5)
Muriate of potash	- 60% (K_2O)

No additional fertilizers were supplied for the intercrops. Phosphorus and potassium were applied entirely as basal. Nitrogen was applied in two equal splits after the first (69 DAP) and second cut (104 DAP) of guinea grass.

Method of planting

Guinea grass

Old clumps were uprooted and young healthy slips with roots were separated for planting. The spacings followed were as per the treatments and planting was done on 24-6-1987.

Cowpea

The seeds were sown in rows in the interspace of guinea grass at the rate of two seeds per hole immediately after planting guinea grass to maintain the number of rows as per treatment.

Maize

The seeds were sown in rows at the rate of two seeds per hole in the interspace of guinea grass immediately after planting guinea grass to maintain the number of rows as per treatment.

Gap filling

Gap filling was done uniformly in all crops on the seventh day after sowing to ensure uniform stand.

Plant protection

There was no serious incidence of pests and diseases and hence no plant protection measures were taken.

Irrigation

One light irrigation was given immediately after sowing. Subsequently light irrigations were given on alternate days during dry spells.

Thinning

Sequential thinning of intercrops were done as per treatment and the quantity of fresh fodder added to the total biomass of the system, was recorded.

Harvest

The final harvest of cowpea was done at 53 DAS and that of maize was done on 75 DAS. The first, second and third cuts of guinea grass were taken respectively at 69, 104 and 132 days after planting. After harvesting the intercrops (Maize and cowpea) guinea grass was allowed to grow alone without raising intercrops.

Observations recorded

1. Vegetative characters

1.1 Total fresh fodder yield from the system

Fresh fodder yields of both base crop and intercrops from net area were recorded immediately after harvest. Green fodder yields of both base and intercrops in each plot were added to get total fresh fodder yield from the system. In the treatments where thinning of intercrops was followed, quantities of fresh fodder harvested at 30 and 50 DAS were also added to this. Total fresh fodder yield was calculated at three stages namely, 75, 104 and 132 DAP, coinciding with final harvest of maize and 2nd and 3rd cuts of guinea grass respectively.

1.2 Land Equivalent Ratio (LER)

LER was calculated using the formulae as suggested by Chatterjee and Maiti (1982).

$$LER = \frac{\text{Yield in intercropping system}}{\text{Sole crop yield}}$$

1.3 Total dry fodder yield from the system

Fresh weight and dry weight of guinea grass, maize and cowpea samples were recorded and moisture percentage was estimated. Using the data on the moisture per cent and fresh weight, the dry matter yield was worked out.

Dry fodder yields of both base and intercrops in each plot were added to get total dry fodder yield from the system. In the treatments where thinning of intercrops was followed, quantities of dry fodder yield harvested at 30 and 50 DAS were also added to this. Total dry fodder yields were calculated at three stages namely, 75, 104 and 132 DAP coinciding with final harvest of maize and 2nd and 3rd cuts of guinea grass respectively.

1.4 Leaf stem ratio

The plant samples taken to record the dry matter production were separated into leaf and stem weighed and the ratio was calculated for both base and intercrops.

2. <u>Incidence of weeds</u>

2.1 Weed dry weight

Weeds collected from 1 x 1 m area of the net plot were oven dried at 80 $\pm$ 5^oC till a constant weight was obtained. Dry weight of weed was recorded at 3 weeks and 6 weeks after planting.

3. Quality characteristics

3.1 Protein yield from the system

The total nitrogen contents of the samples collected at different stages were determined by modified Micro Kjeldahl method (Jackson, 1967) and crude protein was calculated by multiplying the nitrogen content by the factor 6.25 (Simpson et al 1965). The crude protein yield was calculated by multiplying the crude protein content by dry matter yield.

Protein yields of both base and intercrops in each plot were separately worked out and added to get the total protein yield from the system. In the treatments where thinning of intercrops was followed protein yield harvested at 30 and 50 DAS were also added to this. Total protein yield from the system was calculated at three stages namely 75, 104 and 132 DAP.

4. Nutrient uptake

4.1 Uptake of nitrogen by crops

From the nitrogen content of samples and dry matter yield nitrogen uptake by crops was calculated. Nitrogen uptake of both base and intercrops in each plot was added to get total nitrogen uptake from the system. In the treatments where thinning of intercrops was followed, nitrogen uptake at 30 and 50 DAS were separately worked out and also added to this. Total nitrogen uptake from the system was calculated at three stages, namely 75, 104 and 132 DAP.

4.2 Uptake of phosphorus by crops

Phosphorus content of samples were estimated following the procedure suggested by Jackson (1967). From the phosphorus content of samples and dry matter yield, phosphorus uptake by crops was calculated. Phosphorus uptake of both base and intercrops in each plot was added to get total phosphorus uptake from the system. In the treatments where thinning of intercrops was followed, phosphorus uptake at 30 and 50 DAS were separately worked out and also added to this. This has been done at three stages namely 75, 104 and 132 DAP.

4.3 Uptake of potassium by crops

Potassium contents of sample were estimated following the procedure suggested by Jackson (1967). From the potassium content of samples and dry matter yield potassium uptake was calculated. Potassium uptake of both base and intercrops in each plot was added to get the total potassium uptake from the system. In the treatments where thinning of intercrops was followed, potassium uptake at 30 and 50 DAS were separate. worked out and also added to this. This has been done at three stages, namely 75, 104 and 132 DAP.

5. Soil analysis

Soil samples collected before and after the experiment were analysed for total nitrogen and organic carbon (Jackson, 1967).

6. Economics

Economics of production of fodder was calculated with the following assumptions.

1. Cost of cultivation for guinea grass @ Rs.4,938/- ha. (based on cost of cultivation arrived at the Instructional farm attached to the College of Agriculture, Vellayani).

2. Additional cost for intercropping (for treatments T_1 to T_{10}).

T_1	- Nil
T_2	- Nil
T_3	- Rs.530/- ha
T_4	- Rs.840/- ha
T_5	- Rs.1,110/- ha
T_6	- Rs.1,687/- ha
T_7	- Rs.397/- ha
T_8	- Rs.700/- ha
T_9	- Rs.897/- ha
T_{10}	- Rs.1,400/- ha
T_{11}	- Rs.2,640/- ha (total cost of cultivation)
T_{12}	- Rs.2,500/- ha (" ")

Prices of fresh fodder

(i)	Guinea grass	- Rs.150/ tonne	(Sale price followed at the District Livestock Farm, Kodappanakunnu)
(ii)	Maize	- Rs.200/ t	
(iii)	Cowpea	- Rs.200/ t	

Benefit-cost ratio of each system was also worked out.

7. Statistical analysis

The data collected were analysed statistically by applying the technique of analysis of variance for Randomised Block Design (Snedecor and Cochran, 1967) and significance was tested by 'F' test.

RESULTS

RESULTS

The experimental data were subjected to statistical analysis to bring out the treatment differences. Results obtained from the study are presented below.

A. Total fresh fodder yield

Data on total fresh fodder yield recorded at 75, 104 and 132 DAP are presented in Table 2 and Figures 3 and 4 and their analysis of variance in Appendix II a.

The results revealed that there was no difference in fresh fodder yield between normally planted (60 x 30 cm) and paired row planted (30 x 30/90 cm) guinea grass.

Intercropping of maize in the interspace of guinea grass both under normal as well as paired row planting resulted in a considerable improvement in total biomass production compared to sole cropping of guinea grass. Similarly growing of cowpea in the interspace of paired row planted guinea grass (30 x 30/90 cm) also resulted in greater improvement in total biomass productivity when compared to sole cropping. This trend was observed at all stages viz. 75, 104 and 132 DAP.

Table 2. Total fresh fodder yield from the system

Treatment No.	Treatments	Fresh fodder yield (t/ha) At 75 DAP	At 104 DAP	At 132 DAP	Per day production(kg/day) 75 DAP	104 DAP	132 DAP
T_1	GG 60 x 30 cm	13.61	28.15	42.19	181.46	270.67	319.62
T_2	GG 30 x 30/90 cm	11.02	25.02	38.35	146.93	240.58	290.53
T_3	GG 60 x 30 cm + 2 row M	24.52	37.33	50.25	326.93	358.94	380.68
T_4	GG 30 x 30/90 cm + 4 row M	22.64	36.40	49.60	301.87	350.00	375.76
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	22.44	34.48	47.67	299.20	331.54	361.14
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	24.04	35.76	48.41	320.53	343.85	366.74
T_7	GG 60 x 30 cm + 3 row CP	15.20	29.40	44.68	202.67	282.69	338.48
T_8	GG 30 x 30/90 cm + 6 row CP	17.56	32.45	48.43	234.13	312.02	366.89
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	17.98	32.31	48.09	239.73	310.67	364.32
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	18.36	31.94	48.26	244.80	307.12	365.61
T_{11}	Maize 30 x 15 cm	22.98	22.98	22.98	306.40		
T_{12}	Cowpea 20 x 10 cm	15.28	15.28	15.28	203.73		
	SEm $\pm$	1.17	1.56	2.02			
	CD (0.05)	3.43	4.60	5.93			

GG - Guinea grass　　M - Maize　　CP - cowpea

DAS - Days after sowing　　DAP - Days after planting

Among the cropping systems tested the biomass productivity was highest in the system involving guinea grass + maize (at 75 DAP) compared to guinea grass + cowpea. But at 104 and 132 DAP, the total dry fodder yield from 'guinea grass + maize' and 'guinea grass + cowpea' intercropping systems were similar. The results indicate that the effect of both maize and cowpea (as intercrops) in guinea grass are similar on total fodder production. Results further revealed that both maize and cowpea are suitable intercrops in guinea grass.

It was also found that sequential thinning of intercrops (both maize and cowpea) did not result in markedly improving the total fresh fodder production from the system.

Among the sole crops (maize and cowpea) fresh fodder yield from maize was the highest (22.98 t/ha) as compared to cowpea (15.20 t/ha).

B. Land equivalent ratio (LER)

The data on LER are given in Table 5.

Among the cropping systems tested, total LER was highest in guinea grass + maize intercropping system than guinea grass + cowpea intercropping system.

Table 3. Total dry fodder yield from the system

Treatment No.	Treatments	Total dry fodder yield (t/ha)			Per day production (kg/day)		
		At 75 DAP	At 104 DAP	At 132 DAP	75 DAP	104 DAP	132 DAP
T_1	GG 60 x 30 cm	2.38	6.77	10.96	31.73	65.09	83.03
T_2	GG 30 x 30/90 cm	1.67	5.04	9.60	22.60	48.46	72.73
T_3	GG 60 x 30 cm + 2 row M	5.85	9.47	13.54	78.00	91.06	102.58
T_4	GG 30 x 30/90 cm + 4 row M	4.63	8.74	12.38	61.73	84.04	96.06
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	4.71	7.99	11.97	62.80	76.83	90.68
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	4.58	7.66	10.98	61.06	73.65	83.18
T_7	GG 60 x 30 cm + 3 row CP	1.97	5.77	10.50	26.26	55.48	79.55
T_8	GG 30 x 30/90 cm + 6 row CP	2.17	6.07	10.88	28.93	58.36	82.42
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	2.37	6.47	12.12	31.60	62.21	91.82
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	2.56	6.89	12.51	34.13	66.25	94.77
T_{11}	Maize 30 x 15 cm	5.85	5.85	5.85	78.00		
T_{12}	Cowpea 20 x 10 cm	1.94	1.94	1.94	25.86		
	SEm ±	0.39	0.60	0.74			
	CD (0.05)	1.15	1.79	2.19			

GG - Guinea grass M - Maize CP - Cowpea

DAS - Days after sowing DAP - Days after planting.

Table 4. Fresh fodder yield and dry fodder yield at 1st, 2nd and 3rd cut of guinea grass (t/ha)

Treatment No.	Treatments	Fresh fodder yield				Dry fodder yield			
		1st	2nd	3rd	Total	1st	2nd	3rd	Total
T_1	GG 60 x 30 cm	13.611	14.537	14.043	42.19	2.38	4.39	4.19	10.96
T_2	GG 30 x 30/90 cm	11.018	13.947	13.333	38.35	1.67	3.37	4.56	9.60
T_3	GG 60 x 30 cm + 2 row M	5.000	12.809	12.917	30.73	0.51	3.62	4.07	8.20
T_4	GG 30 x 30/90 cm + 4 row M	7.099	13.765	13.195	34.06	1.02	4.11	3.94	9.07
T_5	GG 30 x 30/90 cm + 6 row M	7.778	12.037	13.194	33.01	0.83	3.28	3.98	8.09
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	8.796	11.883	12.654	33.33	1.40	3.08	3.32	7.80
T_7	GG 60 x 30 cm + 3 row CP	1.111	14.198	15.278	30.60	0.15	3.80	4.73	8.68
T_8	GG 30 x 30/90 cm + 6 row CP	1.759	14.892	15.972	32.63	0.18	3.90	4.81	8.89
T_9	GG 30 x30/90 cm + 9 row CP thinned to 6 at 30 DAS	3.766	14.352	15.756	33.88	0.50	4.10	5.65	10.25
T_{10}	GG 30 x 30/90cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	3.395	13.580	16.312	33.33	0.53	4.33	5.62	10.48

GG - Guinea grass   M - Maize   CP - Cowpea

DAS - Days after sowing   DAP - Days after planting

Table 5. Land Equivalent Ratio (LER) and Land Equivalent co-efficient (LEC) indicating the yield advantages of guinea grass + maize / cowpea intercropping system.

Treat-ment No.	Treatments	Yield kg/ha		LER		Total LER	LEC
		GG	Inter-crop	GG	Inter-crop		
T_1	GG 60 x 30 cm	13.61	-	1.00	-	1.00	1.000
T_2	GG 30 x 30/90 cm	11.02	-	1.00	-	1.00	1.000
T_3	GG 60 x 30cm + 2 row M	5.00	19.52	0.37	0.85	1.22	0.315
T_4	GG 30 x 30/90 cm + 4 row M	7.10	15.54	0.64	0.68	1.32	0.430
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	7.78	14.66	0.71	0.64	1.35	0.450
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	8.80	15.08	0.80	0.66	1.46	0.535
T_7	GG 60 x 30 cm + 3 row CP	1.11	14.08	0.08	0.92	1.00	0.074
T_8	GG 30 x 30/90 cm + 6 row CP	1.76	15.80	0.16	1.03	1.19	0.160
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	3.77	14.21	0.34	0.93	1.27	0.310
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	3.40	14.96	0.31	0.98	1.29	0.304
T_{11}	Maize 30 x 15 cm		22.98	-	1.00	1.00	1.000
T_{12}	Cowpea 20 x 10 cm		15.28	-	1.00	1.00	1.000

GG - Guinea grass M - Maize CP - Cowpea

DAS - Days after sowing.

C. Total dry fodder yield

The data on the total dry fodder yield are given in Table 3 and Figs. 5 and 6 and the analysis of variance in Appendix IIa.

The total dry fodder yield from different cropping systems followed a more or less similar trend as that of the total fresh fodder yield.

As in the case of total fresh fodder yield, change in planting geometry did not influence the total dry fodder yield from the system.

Intercropping in guinea grass with maize was beneficial to increase the dry fodder yield and planting 2 rows of maize in normally planted guinea grass (60x30 cm) gave higher dry matter yield than solo cropping of guinea grass.

Among the various cropping systems, dry matter productivity was the highest with the system involving guinea grass + maize, than guinea grass + cowpea at 75 and 104 DAP. But at 132 DAP, total dry fodder yield from the guinea grass + maize and guinea grass + cowpea intercropping systems were similar.

It was also observed that sequential thinning of intercrops (both maize and cowpea) did not result in any remarkable improvement in the total production of dry fodder from the system.

Among the sole crops of maize and cowpea dry fodder yield from maize was the highest (5.85 t/ha) as compared to cowpea (1.94 t/ha).

L. Leaf-stem ratio

The data on leaf-stem ratio are given in Table 6 and the analysis of variance in Appendix- II(b).

There was no difference in leaf-stem ratio between guinea grass raised in normal planting (60 x 30 cm) and paired row planting (30 x 30/90 cm). But intercropping has altered the leaf-stem ratio. While guinea grass + maize intercropping decreased the leaf-stem ratio, guinea grass + cowpea intercropping increased it. Highest leaf-stem ratio of 1.72 was noticed with T_{10} (guinea grass 30 x 30/90 cm + 12 rows of cowpea, thinned to 9 at 30 DAS and further to 6 at 50 DAS) although its effect was on par with rest of the guinea grass + cowpea intercropping system tested.

It was also found that sequential thinning of intercrops (both maize and cowpea) did not result in any change in leaf-stem ratio of fodder from the system.

Between the sole crops (maize and cowpea) maize had the lowest leaf-stem ratio (0.27). Cowpea had a leaf-stem ratio of 1.75.

Table 6. Leaf-stem ratio

Treatment No.	Treatments	Leaf-stem ratio		
		At 75 DAP	At 104 DAP	At 132 DAP
T_1	GG 60 x 30 cm	1.29	1.41	1.70
T_2	GG 30 x 30/90 cm	1.37	1.49	1.75
T_3	GG 60 x 30 cm + 2 row M	0.91	1.19	1.68
T_4	GG 30 x 30/90 cm + 4 row M	0.84	1.19	1.72
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	0.95	1.34	1.67
T_6	GG 30 x 30/90cm + 8 row M thinned to 6 at 30 DAS further to 4 at 50 DAS	0.96	1.26	1.65
T_7	GG 60 x 30cm + 3 row CP	1.49	1.50	1.79
T_8	GG 30 x 30/90 cm + 6 row CP	1.54	1.58	1.86
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	1.54	1.58	1.86
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	1.72	1.74	1.95
T_{11}	Maize 30 x 15 cm	0.27	0.27	0.27
T_{12}	Cowpea 20 x 10 cm	1.75	1.75	1.75
	SEm ±	0.10	0.07	0.07
	CD(0.05)	0.29	0.23	0.21

GG - Guinea grass   M - Maize   CP - Cowpea

DAS - Days after sowing   DAP - Days after planting

E. Protein yield

The data on protein yield are given in Table 7 and Figs. 7 & 8 and the analysis of variance in Appendix II(a).

There was no difference in protein yield between guinea grass planted in normal planting (60 x 30 cm) and paired row planting (30 x 30/90 cm).

The total protein yield was highest from the cropping system involving guinea grass + maize at early stage (75 DAP). But when estimated at 132 DAP, it was found that the total protein yield was highest from the cropping system involving guinea grass + cowpea.

Sequential thinning of intercrops (both maize and cowpea) did not result in any improvement in total protein yield from the system.

Among the sole crops of maize and cowpea, protein yield from maize was the highest (837 kg/ha) as compared to cowpea (403 kg/ha).

F. Weed dry weight

The data on weed dry weight are presented in Table 8 and the analysis of variance in Appendix II b.

There was no difference in the incidence of weeds due to change in planting geometry of the base crop.

Table 7. Total protein yield from the system (kg/ha)

Treatment No.	Treatments	Total protein yield At 75 DAP	At 104DAP	At 132 DAP	Per day production (kg/day) 75DAP	104DAP	132 DAP
T_1	GG 60 x 30 cm	309	1090	1634	4	10	14
T_2	GG 30 x 30/90 cm	227	792	1535	2	8	12
T_3	GG 60 x 30 cm + 2 row M	593	1048	1578	8	10	12
T_4	GG 30 x 30/90 cm + 4 row M	401	922	1421	5	9	11
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	639	1043	1564	9	10	12
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	468	899	1273	6	8	10
T_7	GG 60 x 30 cm + 3 row CP	404	999	1733	5	10	13
T_8	GG 30 x 30/90 cm + 6 row CP	426	1050	1844	6	10	14
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	415	1096	2092	6	11	16
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	460	1205	2205	6	12	17
T_{11}	Maize 30 x 15 cm	837	837	837	11		
T_{12}	Cowpea 20 x 10 cm	403	403	403	7		
	SEm ±	61	109	117			
	CD (0.05)	182	321	344			

GG - Guinea grass M - Maize CP - Cowpea

DAS - Days after sowing DAP - Days after planting

Table 8. Weed dry weight

Treatment No.	Treatments	Weed dry weight (kg/ha)	
		At 3 WAP	At 6 WAP
T_1	GG 60 x 30 cm	38.12	40.20
T_2	GG 30 x 30/90 cm	58.80	53.09
T_3	GG 60 x 30 cm + 2 row M	59.03	26.49
T_4	GG 30 x 30/90 cm + 6 row M	43.36	22.07
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	38.81	17.52
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	28.78	14.97
T_7	GG 60 x 30 cm + 3 row CP	46.22	21.60
T_8	GG 30 x 30/90 cm + 6 row CP	21.91	15.20
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	22.07	11.11
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	5.63	7.02
T_{11}	Maize 30 x 15 cm	129.55	53.40
T_{12}	Cowpea 20 x 10 cm	20.45	20.68
	SEm±	11.27	7.44
	CD(0.05)	33.07	21.84

GG - Guinea grass M - Maize CP - Cowpea

DAS - days after sowing DAP - Days after planting

WAP - Weeks after planting

However, considerable reduction in weed growth was due to intercropping with cowpea and maize. The reduction was prominent with advancement of growth as well as with increase in the number of rows of intercrops in the intercropping system.

It was also observed that sequential thinning of intercrops (maize and cowpea) did not result any change in weed growth.

The weed growth was highest in maize fields (sole crop) compared to cowpea fields.

G. Nutrient uptake

1. Nitrogen uptake

The data on nitrogen uptake are given in Table 9 and analysis of variance in Appendix II b.

There was no difference in nitrogen uptake between guinea grass planted in normal spacing (60 x 30 cm) and in paired row spacing (30 x 30/90 cm). The total nitrogen uptake was highest from the system involving guinea grass + maize at early stages (75 and 104 DAP). But when estimated at 132 DAP, it was found that total nitrogen uptake was highest from the cropping system involving 'guinea grass + cowpea'.

It was also noted that sequential thinning of intercrops (both maize and cowpea) did not result in any improvement in total nitrogen uptake from the system.

Table 9. Nitrogen uptake from the system (kg/ha)

Treatment No.	Treatments	Total nitrogen uptake		
		Upto 75 DAP	Upto 104 DAP	Upto 132 DAP
T_1	GG 60 x 30 cm	50	155	261
T_2	GG 30 x 30/90 cm	36	127	246
T_3	GG 60 x 30 cm + 2 row M	95	168	253
T_4	GG 30 x 30/90 cm + 4 row M	64	148	227
T_5	GG 30 x 30/90 cm 6 row M thinned to 4 row at 30 DAS	102	167	250
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	75	136	204
T_7	GG 60 x 30 cm + 3 row CP	65	159	277
T_8	GG 30 x 30/90 cm + 6 row CP	68	168	295
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	66	175	335
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	74	193	353
T_{11}	Maize 30 x 15 cm	134	134	134
T_{12}	Cowpea 20 x 10 cm	65	65	65
	SEm±	9	15	18
	CD(0.05)	29	47	53

GG - Guinea grass M - Maize CP - Cowpea

DAS - Days after sowing DAP - Days after planting

Among the sole crops (maize and cowpea) nitrogen uptake was the highest in maize (134 kg/ha) as compared to cowpea (65 kg/ha).

2. Phosphorus uptake

The data on phosphorus uptake are given in Table 10 and the analysis of variance in Appendix III.

There was no difference in phosphorus uptake between guinea grass planted in normal spacing (60 x 30 cm) and in paired rows (30 x 30/90 cm).

The phosphorus uptake from guinea grass + maize and guinea grass + cowpea intercropping system were higher compared to guinea grass sole cropping.

The phosphorus uptake from the system involving guinea grass + maize and guinea grass + cowpea were more or less similar.

It was also found that sequential thinning of intercrops (both maize and cowpea) did not result in any change in phosphorus uptake from the system.

Among the sole crops of maize and cowpea, phosphorus uptake was the highest with maize (15.37 kg/ha).

Table 10. Phosphorus uptake from the system (kg/ha)

Treatment No.	Treatments	Total phosphorus uptake		
		Upto 75 DAP	Upto 104 DAP	Upto 132 DAP
T_1	GG 60 x 30 cm	8	24	38
T_2	GG 30 x 30/90 cm	5	17	33
T_3	GG 60 x 30 cm + 2 row M	12	24	38
T_4	GG 30 x 30/90 cm + 4 row M	10	25	39
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	11	22	35
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	11	22	32
T_7	GG 60 x 30 cm + 3 row CP	8	24	43
T_8	GG 30 x 30/90 cm + 6 row CP	10	25	42
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	10	26	45
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	11	27	47
T_{11}	Maize 30 x 15 cm	15	15	15
T_{12}	Cowpea 20 x 10 cm	8	8	8
	SEm ±	1	2	3
	CD(0.05)	3	6	8

GG - Guinea grass M - Maize CP - Cowpea

DAS - Days after sowing DAP - Days after planting

3. Potassium uptake

The data on potassium uptake are given in Table 11 and the analysis of variance in Appendix IIIa.

Change in the planting geometry did not cause any change in potassium uptake by guinea grass.

The potassium uptake was highest in guinea grass + maize intercropping system compared to guinea grass sole cropping or guinea grass + cowpea intercropping at 75 DAP. But at 132 DAP, potassium uptake was more from the system involving guinea grass + cowpea intercropping as compared to guinea grass sole cropping. The potassium uptake from the two intercropping systems (guinea grass + maize and guinea grass + cowpea) did not differ much.

The potassium uptake was not affected by sequential thinning of intercrops also.

Between the sole crops of maize and cowpea, potassium uptake was the highest with maize.

H. Soil fertility

Organic carbon and total nitrogen content of soil after the experiment

The data on the organic carbon and total nitrogen content of soil are given in Table 12 and the analysis of variance in Appendix IIIa.

Table 11. Potassium uptake from the system (kg/ha)

Treatment No.	Treatments	Total potassium uptake		
		Upto 75 DAP	Upto 104 DAP	Upto 132 DAP
T_1	GG60 x 30 cm	43	111	135
T_2	GG 30 x 30/90 cm	28	77	115
T_3	GG 60 x 30 cm + 2 row M	91	123	173
T_4	GG 30 x 30/90 cm + 4 row M	79	136	162
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	83	123	153
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	70	113	139
T_7	GG 60 x 30 cm + 3 row CP	45	117	158
T_8	GG 30 x 30/90 cm + 6 row CP	54	120	189
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	57	135	203
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	61	123	177
T_{11}	Maize 30 x 15 cm	93	93	93
T_{12}	Cowpea 20 x 10 cm	47	47	47
	SEm ±	9	12	14
	CD(0.05)	26	36	43

GG - Guinea grass M - Maize CP - Cowpea

DAS - Days after sowing DAP - Days after planting.

Table 12. Soil organic carbon and total nitrogen after the experiment (t/ha)

Treatment No.	Treatments	Soil organic carbon	Soil total nitrogen
T_1	GG 60 x 30 cm	13.08	1.26
T_2	GG 30 x 30/90 cm	12.89	1.33
T_3	GG 60 x 30 cm + 2 row M	11.16	1.02
T_4	GG 30 x 30/90 cm + 4 row M	12.42	1.18
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	13.38	1.15
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	13.50	1.23
T_7	GG 60 x 30 cm + 3 row CP	15.12	1.38
T_8	GG 30 x 30/90 cm + 6 row CP	12.84	1.28
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	15.06	1.46
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	15.42	1.62
T_{11}	Maize 30 x 15 cm	13.70	1.28
T_{12}	Cowpea 20 x 10 cm	15.00	1.44
	SEm ±	0.644	0.072
	CD(0.05)	1.89	0.21

GG - Guinea grass M - Maize CP - Cowpea

DAS - Days after sowing.

There were no differences in organic carbon and total nitrogen contents of the soil due to change in planting geometry of base crop.

The post harvest organic carbon and total nitrogen contents of soil were more or less same in both intercropped as well as sole cropped plots. But between intercropped plots, organic carbon and total nitrogen contents of soil were high in cowpea intercropped plots as compared to maize intercropped plots.

Sequential thinning of intercrops did not influence the fertility of soil after harvest.

I. Economic of Intercropping

The data on economics are given in Table 13 and the analysis of variance in appendix III b.

The net return from guinea grass was not affected due to change in planting geometry.

The intercropping in guinea grass either with maize or cowpea could increase net return as compared to sole cropping. Intercropping of 2 rows of maize in between normally planted guinea grass (60 x 30 cm) resulted in the highest amount of net return (T_3). Net return obtained from this cropping system was similar to that of T_4 (guinea grass 30 x 30/90 cm 4 rows of maize intercropping system). Effect of these two

Table 10. Economics of Intercropping

Treatment No.	Treatments	Cost of cultivation for guinea grass Rs.	Addl. cost for Intercropping. Rs.	Total cost of cultivation. Rs.	Yield of fodder		Mean Net Profit	Benefit cost ratio (Mean)
					Guinea grass (t/ha)	Maize / Cowpea (t/ha)		
T_1	GG 60 x 30 cm	4938	-	4938	42.19	-	1390.70	1.281
T_2	GG 30 x 30/90 cm	4938	-	4938	38.35	-	814.30	1.165
T_3	GG 60 x 30 cm + 2 row M	4938	530	5468	30.73	19.52	3044.98	1.557
T_4	GG 30 x 30/90 cm + 4 row M	4938	840	5778	34.06	15.54	2438.80	1.422
T_5	GG 30 x 30/90 cm + 6 row M thinned to 4 row at 30 DAS	4938	1110	6048	33.01	14.66	1835.43	1.303
T_6	GG 30 x 30/90 cm + 8 row M thinned to 6 at 30 DAS and further to 4 at 50 DAS	4938	1687	6625	33.33	15.08	1390.38	1.210
T_7	GG 60 x 30 cm + 3 row CP	4938	397	5335	30.60	14.08	2147.28	1.403
T_8	GG 30 x 30/90 cm + 6 row CP	4938	700	5638	32.63	15.80	2416.02	1.429
T_9	GG 30 x 30/90 cm + 9 row CP thinned to 6 at 30 DAS	4938	897	5835	33.88	14.21	2088.63	1.359
T_{10}	GG 30 x 30/90 cm + 12 row CP thinned to 9 at 30 DAS and further to 6 at 50 DAS	4938	1400	6338	33.30	14.96	1648.88	1.260
T_{11}	Maize 30 x 15 cm	-	2640	2640	-	22.98	1955.73	1.741
T_{12}	Cowpea 20 x 10 cm	-	2500	2500	-	15.28	555.53	1.222
	SEm ±						212.28	0.063
	CD(0.05)						981.93	0.185

Cost of guinea grass fodder = Rs.150/t
Cost of Maize/Cowpea fodder = Rs.200/t

GG - Guinea grass M - Maize
CP - Cowpea DAS - Days after sowing.

cropping systems in terms of net profit was also on par with that of guinea grass (30 x 30/90 cm) + 6 rows of cowpea intercropping system (T_8).

The variations in the benefit-cost ratio due to the treatments were similar to that observed with net returns.

DISCUSSION

DISCUSSION

An experiment was conducted at the Instructional farm attached to the College of Agriculture, Vellayani to study the biomass productivity of a forage crop based cropping system involving C_3 and C_4 plants. The two C_4 plants studied were guinea grass and maize while the only C_3 plant involved was cowpea. The guinea grass was used as the base crop while maize and cowpea were used as inter-crops. The results obtained from the study are discussed in the following sections.

1. Total fresh fodder yield

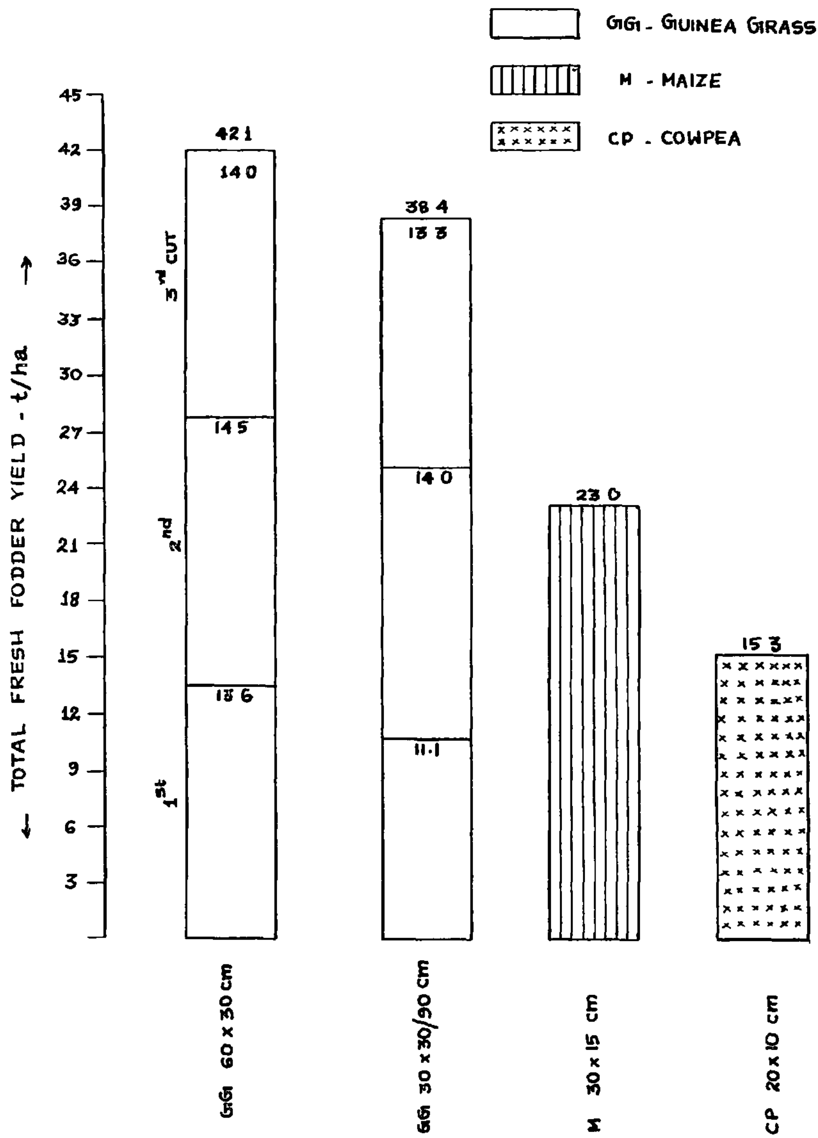
The data revealed that there was no difference in fresh fodder yield between guinea grass planted in normal planting (60 x 30 cm) and in paired row planting (30 x 30/90cm). This is in agreement with the reports that change in planting geometry did not cause any difference in grain yield of ragi (Anon 1974) and grain yield of sorghum (Kunasekharan 1975, Gangaprasad Rao 1975 and Singh 1976). This indicates that plant growth was not limited by the environment resources like solar radiation, moisture and nutrients in the two systems of planting. Further, change in planting geometry might not have caused competition for space between plants. The results thus indicate that there is ample scope for intercropping in the interspace of guinea grass by suitably adjusting planting geometry so as to increase the total fodder productivity.

Both under normally planted and paired row planted guinea grass, intercropping with maize resulted in a considerable improvement in the total fodder production, compared to guinea grass sole cropping. Guinea grass + maize intercropping system has given 21 per cent higher yield than guinea grass sole crop. Highest fodder yield of 50.25 t/ha (upto 132 DAP) was obtained from T_3 (guinea grass 60 x 30cm + 2 rows of maize) followed by T_4 (guinea grass 30 x 30/90 cm + 4 rows of maize). It may be noted that both the base crop as well as the intercrop carry out photosynthesis by C_4 mechanism (Gibbs and Latzko 1979). They are quick growing and efficient users of carbondioxide, water and solar energy (Carlleopard and Paul 1985). Solar energy received in the interspace was tapped by the intercrop thus avoiding wastage. Thus the total productivity of guinea grass + maize system was much higher than guinea grass sole crop. This agrees with the findings of Stråge (1961) who observed that total forage yield increased in the intercropping system (maize + cowpea). Villegas (1956), Dayal *et al* (1967) and Muthuswamy *et al* (1980) also obtained similar results.

Intercropping in guinea grass with cowpea was also beneficial (17 per cent higher) compared to guinea grass sole cropping. Cameron (1969) got 36 per cent increased fodder yield in guinea grass + lucern than in guinea grass sole crop Chandini and Raghavan Pillai (1980) also got higher yield from guinea grass + legume intercropping system than from sole guinea grass system. But in the present study the beneficial effect was observed only in paired row planted guinea grass and not in normally planted guinea grass. Among the guinea grass + cowpea intercropping system, the highest yield of 48.43 t/ha was obtained from T_8(guinea grass 30 x 30/90 cm + 6 rows of cowpea). It may be noted that the intercrop cowpea follows C_3 photosynthetic pathway with slow growth rate (Carlleopard and Paul 1985). It could tap considerable amount of solar energy received in the inter-space resulting in an augmentation of the total fodder production compared to guinea grass sole cropping. Difference in the performance of cowpea between guinea grass grown in paired row system and normal row system might be due to difference in competition factor.

It was found that at 75 DAP, total fodder production from guinea grass + maize cropping system was higher compared to guinea grass + cowpea. Though there was a slight reduction in base crop yield due to intercrops, there is definite

FIG 3 TOTAL FRESH FODDER YIELD FROM SOLE CROPS OF GUINEA GRASS, MAIZE AND COWPEA



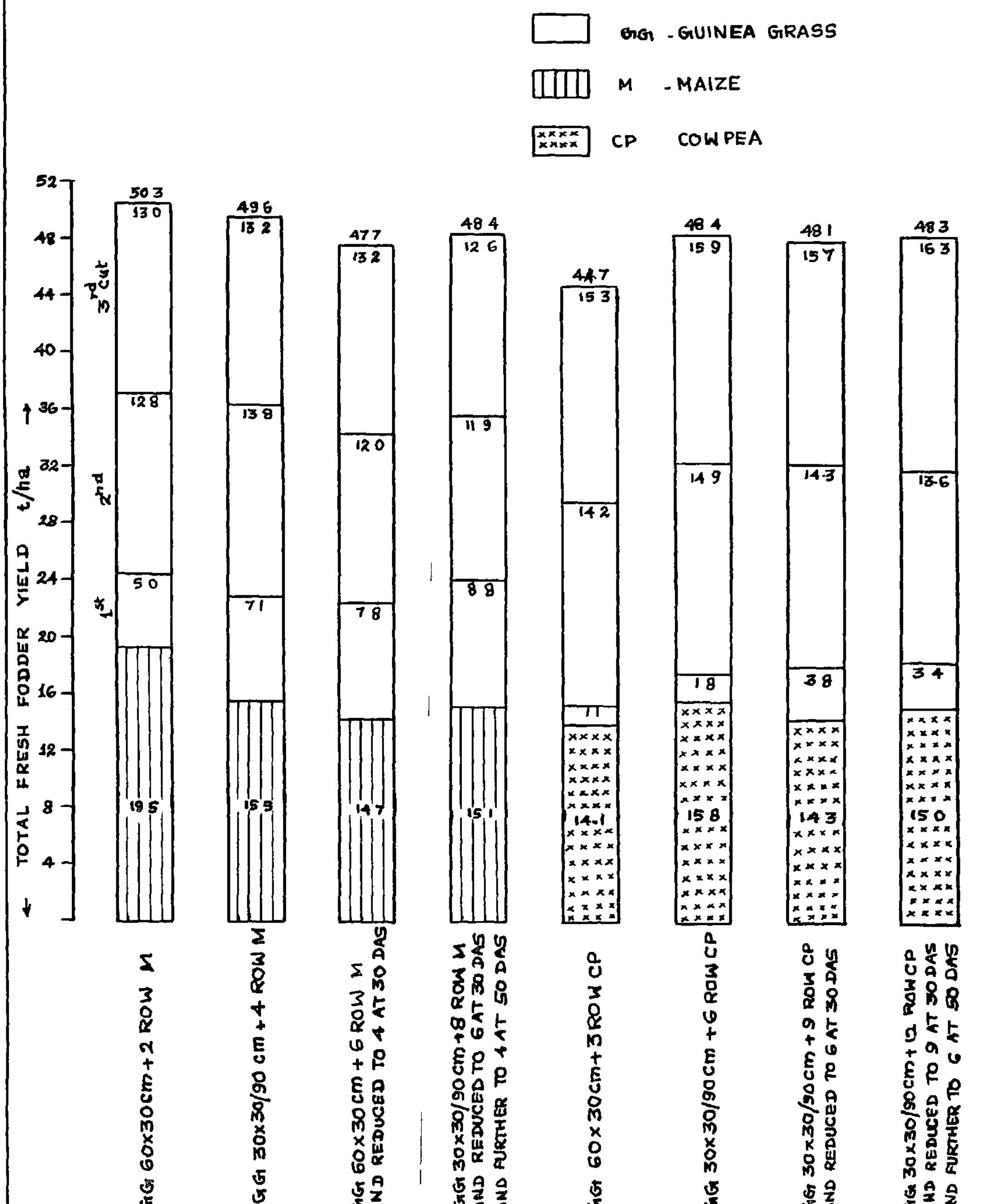
advantage due to intercropping in terms of total biomass production. As the sowing of intercrops coincides with the planting of guinea grass slips, cowpea being twiny and spreading crop, tends to smoother the slips to such an extent as to bring down guinea grass yield. While following intercropping it appears that raising of intercrops after establishment of base crop, say 1 to 2 weeks after planting of base crop decrease the yield reduction of guinea grass. Vikraman Nair _et al_ 1982 got 50.3 per cent reduction in the yield in guinea grass when intercropped with cowpea, but the total forage yield from the system was more. Results of the present study also agree with the above findings.

It was also interesting to note that the cumulative total fodder yields as on 104 and 132 DAP from guinea grass + maize and guinea grass + cowpea were similar. The initial difference in fodder yield observed at 75 DAP between the two intercropping systems can be attributed to their difference in carbon fixing mechanism and the rate of photorespiration between the intercrops. Yield advantage was definitely with the cropping system involving a $C_4 + C_4$ grass system than with C_4 and C_3 grass system. But the gap in the production of guinea grass + cowpea cropping system observed in the initial stage was compensated in the later stages by boosting the base crop yield in subsequent cuts, as evidenced by the data on the guinea grass yield obtained in the 2nd and 3rd cut presented in Table 4. Yields of anjan grass in subsequent cuts were higher in cowpea intercropped plots compared to the yield obtained from pure crop of anjan grass as reported by Chauhan et al (1981). The result of the present study is also in accordance with the above reports.

Increased production of guinea grass in cowpea intercropped plots can be attributed to the complementary effect of leguminous plant by way of nitrogen fixation. When cowpea intercropping has increased the base crop yield (in the 2nd and 3rd cut) there was depression in production of base crop due to maize intercropping (Table 4). Chandini and Raghavan Pillai (1980) have also got a similar increase in fodder yield from the system by growing stylosanthes or cowpea as intercrops in guinea grass than from sole crop of guinea grass. Similar trend in guinea grass + stylosanthes and guinea grass + cowpea are earlier reported (Anon 1975 and 1978). With the above findings we can confirm that inter-cropping with maize/cowpea is beneficial in terms of fresh fodder yield as compared to sole crops.

Contrary to the expectation, there was no improvement in the total fodder production due to sequential thinning.

FIG 4 TOTAL FRESH FODDER YIELD FROM THE INTER CROPPING SYSTEM



It may be noted that fertilizer application was limited to the recommendation of the base crop. Further the soil was low in fertility (Table 1).

In the present study no additional fertilizers were given to the intercrops. The intention was to study the marginal production of fodder by intercropping and sequential thinning from guinea grass environment without adding any nutrients. As the soil was inherently low in fertility both the base crop and intercrop suffered severe competition and could not perform better. It seems that had this experiment been conducted in different nutrient regimes to study the fodder production by sequential thinning the results would have been different.

Of the sole crops of maize and cowpea the performance of maize was best producing 22.92 t/ha in 75 days registering the highest per day productivity (306.4 kg/day) compared to cowpea. This observation is in agreement with the reports of Carlleopard and Paul in 1985 that C_4 plants are highly productive due to their chloroplast dimorphism abundancy chloroplast and negligible photo respiration compared to C_3 plants. From the results and discussions presented in the foregoing sections the following conclusion can be drawn.

(1) Planting geometry does not influence the guinea grass yield and guinea grass can be planted either in normal row (60 x 30 cm) or in paired row (30 x 30/90 cm) without any reduction in the yield.

(2) Both maize and cowpea are suitable intercrops in guinea grass.

(3) Among guinea grass based cropping systems tested guinea grass in normal row (60 x 30 cm) + 2 rows of maize (T_3) or guinea grass in paired row (30 x 30/90 cm) + 4 rows maize (T_4) or guinea grass in paired row (30 x 30/90 cm) + 6 rows of cowpea (T_8) can be recommended as efficient cropping systems in terms of fresh fodder yield.

(4) Sequential thinning of intercrops (maize and cowpea) did not enhance the biomass productivity of the guinea grass based cropping system when the fertilizer application was limited to the requirement of guinea grass alone.

(5) Of the sole crops of maize and cowpea, the biomass productivity was the highest with maize.

2. Land Equivalent Ratio

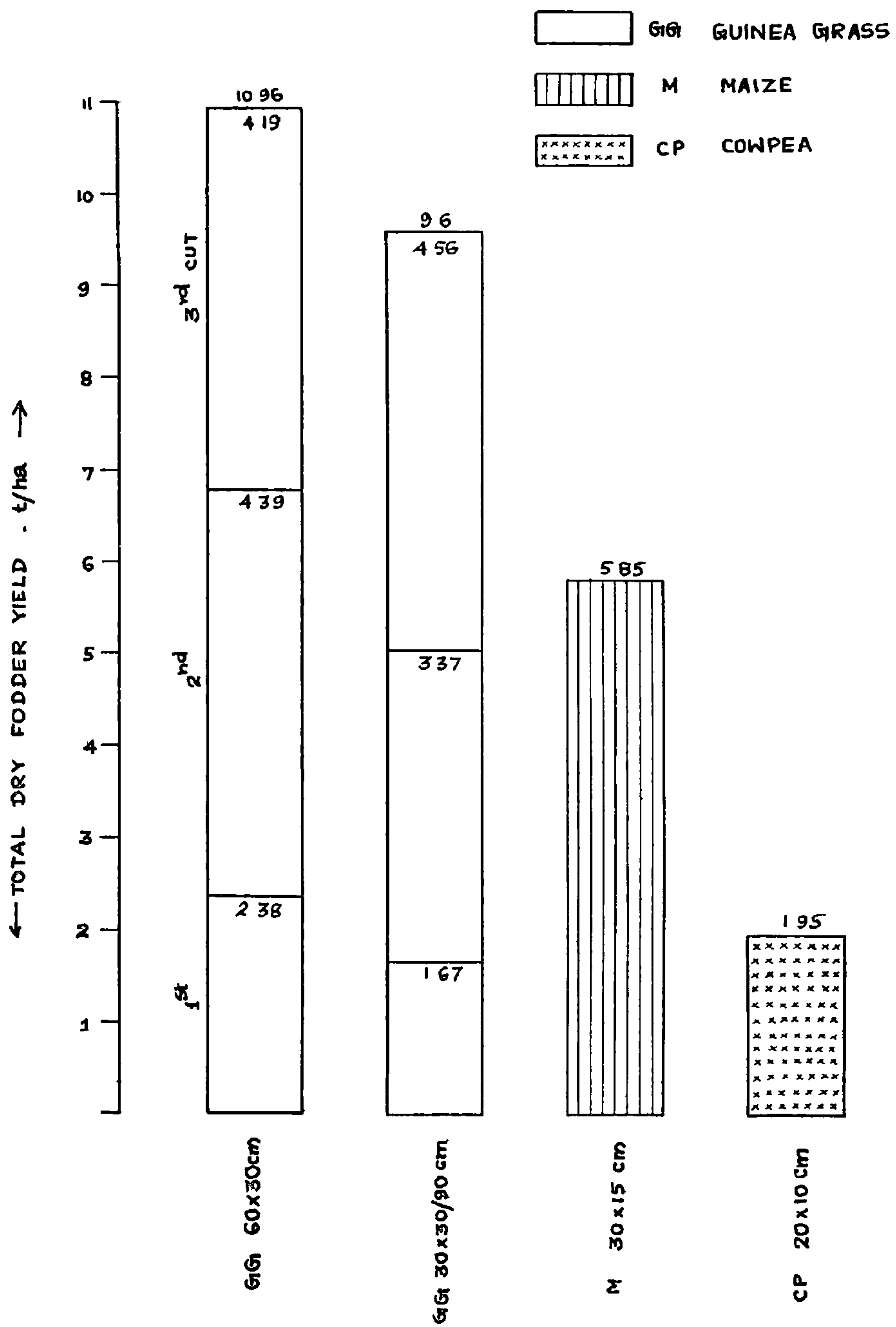
The LER of guinea grass + maize intercropping system was higher than guinea grass + cowpea intercropping system. The fodder production from the guinea grass + maize intercropping system was comparatively higher than that of guinea grass + cowpea intercropping system and hence the LER.

3. Total dry fodder yield

The trend in dry fodder yield under different cropping systems was similar to that observed in fresh fodder yield. The data revealed that dry fodder yields obtained from guinea grass in normal row planting (60 x 30 cm) and paired row planting (30 x 30/90 cm) were similar.

The results indicate that there was tremendous improvement in dry fodder productivity of guinea grass based intercropping system involving maize and cowpea. On an average guinea grass + maize intercropping produced 19 per cent more dry fodder yield compared to guinea grass sole cropping at 132 DAP. Similarly guinea grass + cowpea produced 12 per cent more dry fodder yield compared to guinea grass sole cropping. Krishnaraj (1976) also got similar increase in dry fodder yield from guinea grass + cowpea intercropping system

FIG 5 TOTAL DRY FODDER YIELD FROM SOLE CROPS OF GUINEA GRASS, MAIZE AND COWPEA



compared to sole crop of guinea grass. Chandini and Raghavan Pillai (1980) and Raghavan Pillai (1986) have also confirmed the above findings that dry fodder yield of guinea grass increased due to intercropping with leguminous plant. The results of the present study also agree with the above findings drawn. Highest dry fodder yield of 13.54 t/ha (as on 132 DAP) was obtained from the system T_3 (guinea grass normal planting 60 x 30 cm + 2 rows of maize) followed by T_4 (guinea grass paired row 30 x 30/90 cm + 4 rows of maize).

As in 132 DAP it was found that the performance of guinea grass + maize and guinea grass + cowpea intercropping system was more or less similar in terms of dry fodder yield.

The total dry fodder yield from the cropping system did not change due to intercrops. Among sole crops, more dry fodder yield was produced by maize than cowpea.

The possible reason already explained under fresh fodder yield holds good for the observed trend in dry fodder yield also.

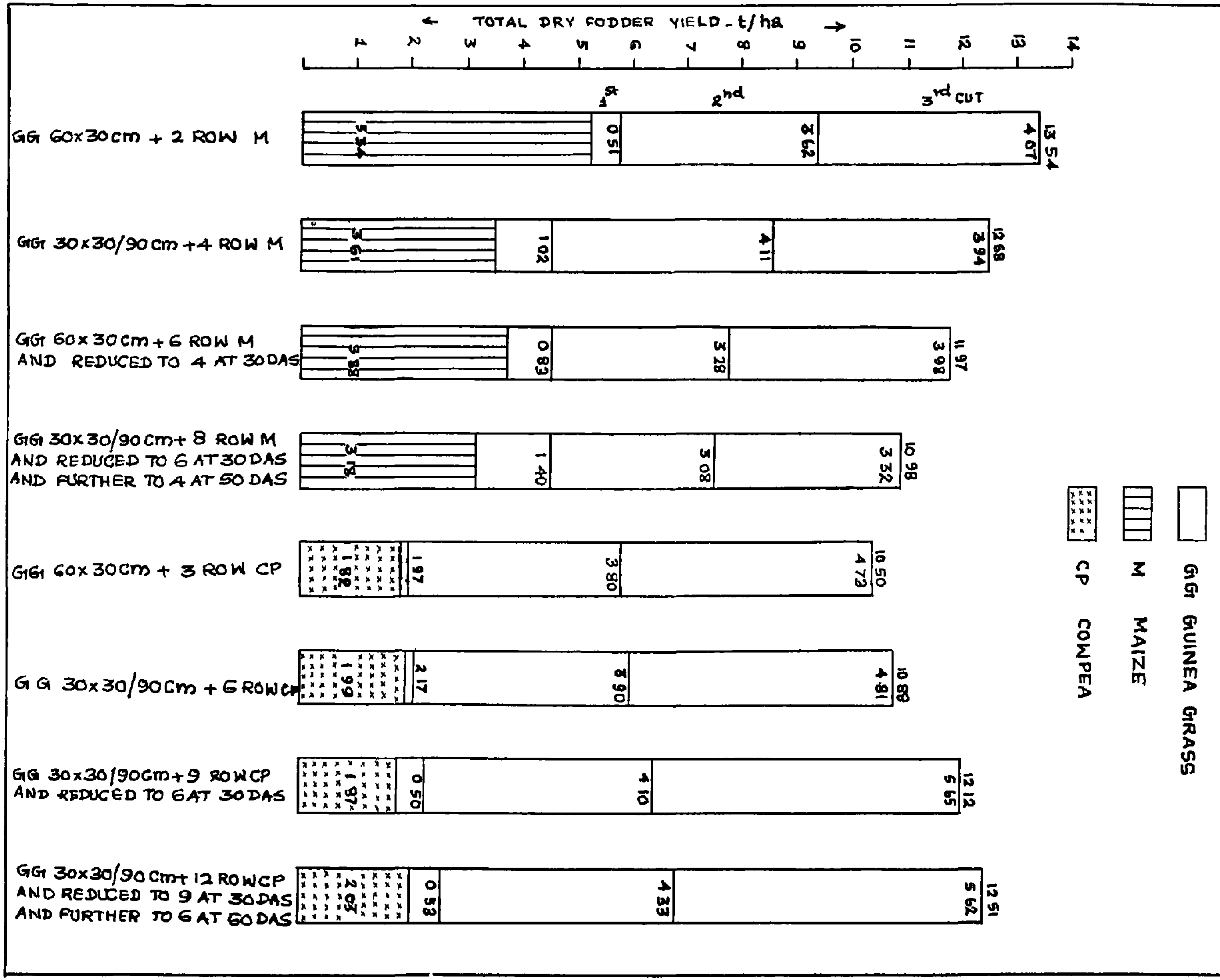


FIG 6

TOTAL DRY FODDER YIELD FROM THE INTERCROPPING SYSTEM

4. <u>Leaf-stem ratio</u>

There was no difference in leaf-stem ratio due to change in planting geometry. There exists a definite relationship between the plant parts in their growth which is known as alleiometric relationship. The result obtained from the present study indicates that the rate of growth of leaf and stem remains more or less the same between the plants raised in the two cropping systems. This means that planting geometry does not influence the alleiometric relations in plant growth and hence leaf-stem ratio.

Compared to fodder yield from guinea grass sole crop, there was a definite increase in leaf-stem ratio of fodder obtained from guinea grass + cowpea intercropping system while there was drastic reduction in leaf-stem ratio of the fodder obtained from guinea grass + maize intercropping system. The difference in leaf-stem ratio of sole crops of maize (0.27) and cowpea (1.75) explains this. Mott (1981) reported that C_3 plants have more leaf stem ratio than C_4 plants. The higher proportion of leaf in cowpea (C_3 plant) compared to maize (C_4 plant) was responsible for observed trend in the leaf-stem ratio of fodder. Raghavan Pillai(1986) reported that guinea grass + stylosanthes intercropping increased the leaf-stem ratio from 1.98 to 2.03 agreeing with results of the present study.

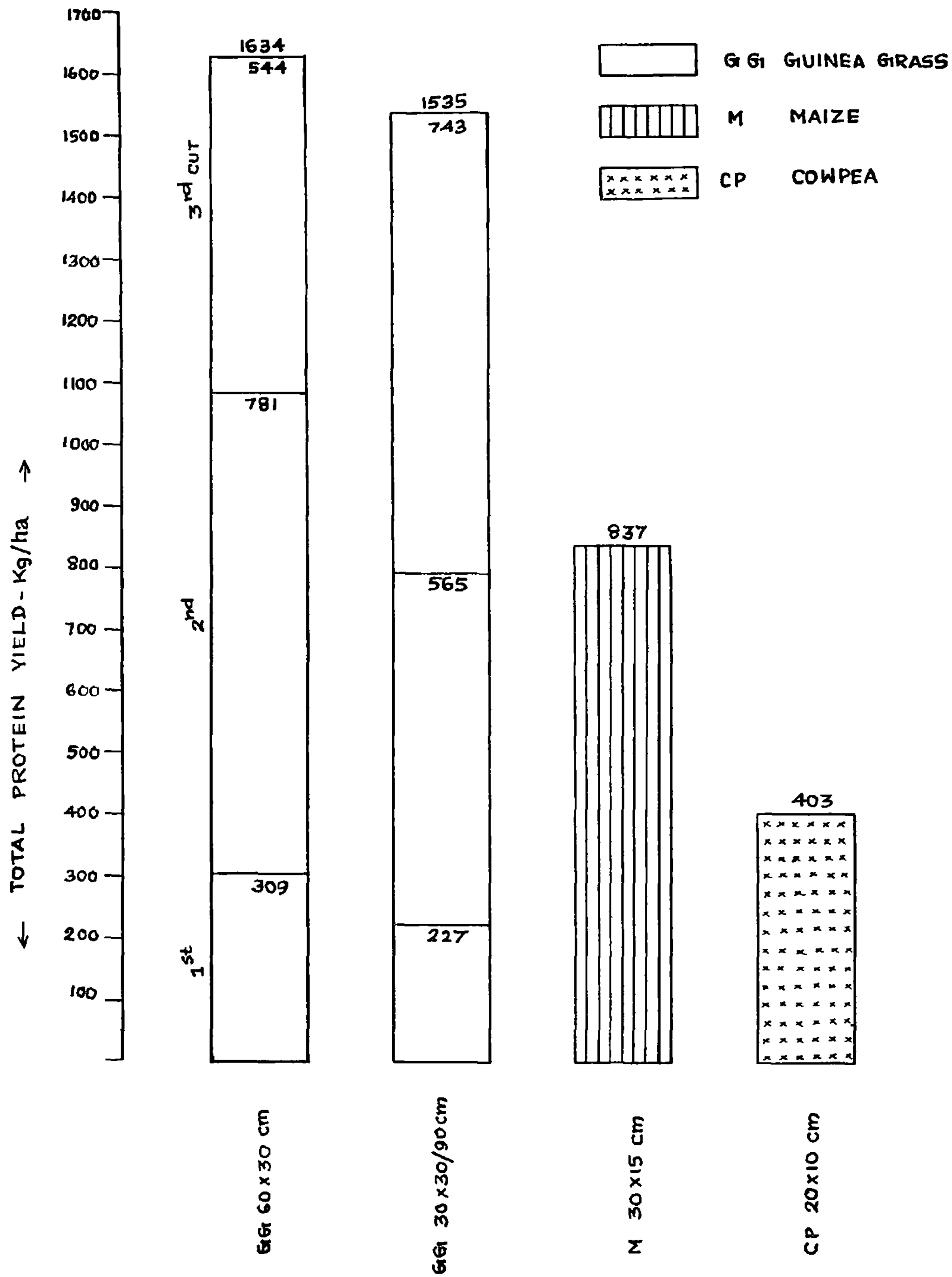
5. Total protein yield

Change in planting geometry did not change the protein yield from guinea grass. It may be noted that there was no difference in the fresh fodder yield (Table 2), dry fodder yield (Table 3) as well as the nitrogen content of plants due to change in planting geometry and hence the protein yield.

There was considerable improvement in the protein yield due to intercropping compared to sole cropping. Similar increase in protein yield due to legume intercropping over sole cropping of fodder grass has been reported by Patel et al (1968) in guinea grass + lucern, Krishnaraj (1976) in guinea grass + cowpea and guinea grass + stylosanthes, Chandini and Raghavan Pillai (1980) in guinea grass + cowpea, Raghavan Pillai (1986) in guinea grass + stylosanthes and Muthuswamy et al (1980) in maize + cowpea.

When estimated at 75 DAP, guinea grass + maize intercropping produced more amount of protein compared to guinea grass + cowpea. This was mainly due to their differential

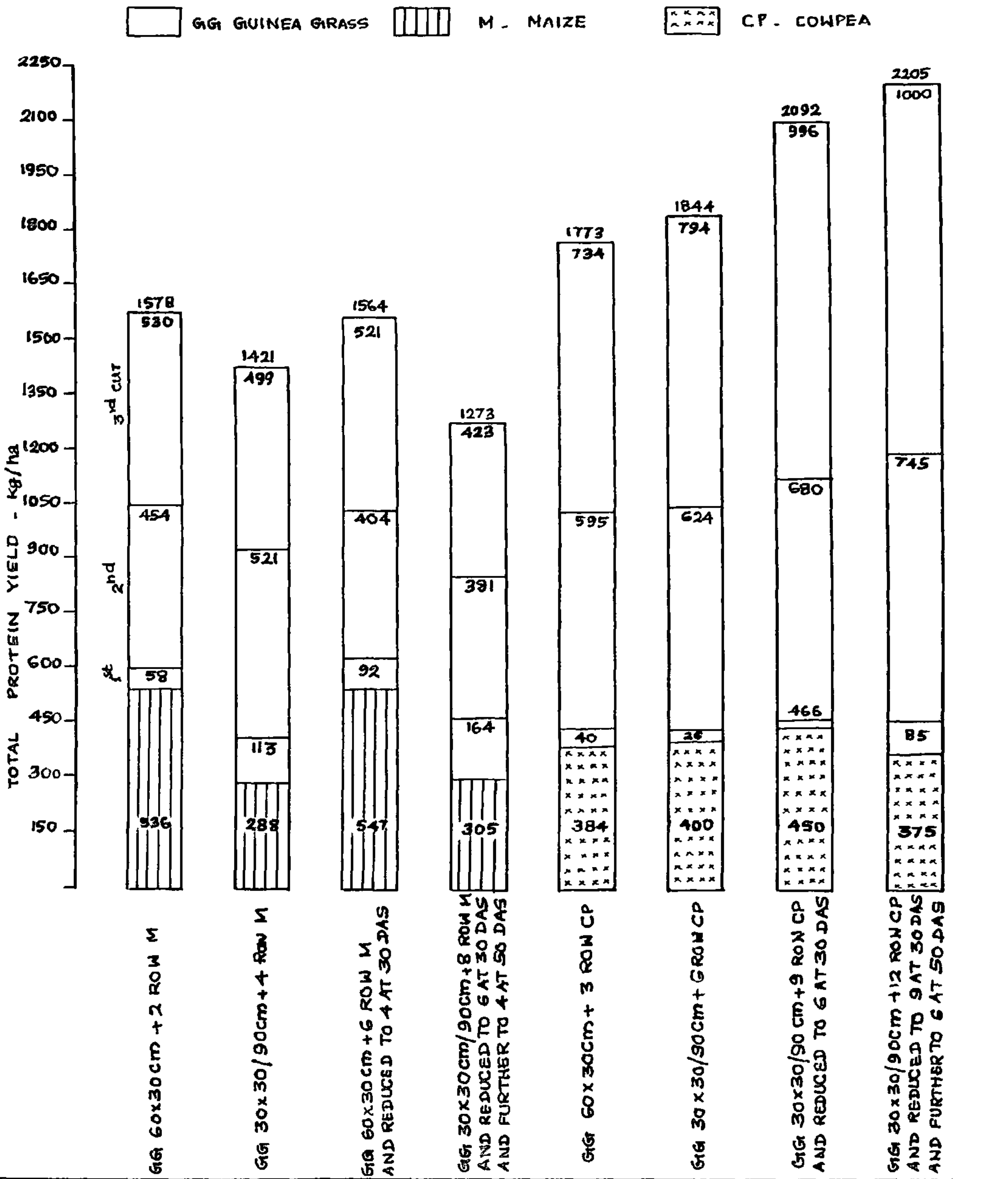
FIG 7 TOTAL PROTEIN YIELD FROM SOLE CROPS OF GUINEA GRASS, MAIZE AND COWPEA



efficiency on fodder production (Fresh fodder yield - Table 2 and dry fodder yield - Table 3) between C_4 and C_3 grass cropping systems. The biomass productivity of $C_4 + C_4$ cropping system was higher than that of $C_4 + C_3$ cropping system, when compared at 75 DAP though the nitrogen content of the guinea grass + cowpea samples was slightly higher than guinea grass + maize samples. But this difference in nitrogen content was more than compensated by the higher biomass production in a $C_4 + C_4$ cropping system compared to $C_4 + C_3$ cropping system.

Subsequently when protein yield was estimated at 104 DAP (coinciding with 2nd cut of guinea grass) there was not much difference in total protein yield between guinea grass + maize or guinea grass + cowpea intercropping system. Interestingly, when the protein yield was estimated at 132 DAP (coinciding with 3rd cut of guinea grass) total protein yield from guinea grass + cowpea intercropping system surpassed the guinea grass + maize system. Data presented in Table 4 reveals that there was considerable improvement in fodder yield of guinea grass (2nd and 3rd cut) obtained from cowpea intercropped plots. This can be attributed to the well known effect of nitrogen fixation by cowpea.

FIG 8 TOTAL PROTEIN YIELD FROM THE INTERCROPPING SYSTEM



This is very clear evident from the data on nitrogen content of soil after the harvest of the crop under cowpea intercropping. As a result total fodder yield and protein yield from guinea grass + cowpea was increased. On an average, there was 24 per cent increase in protein yield in guinea grass + cowpea intercropping system compared to sole cropping. Contrary to the results obtained at 75 DAP, total protein yield from guinea grass + maize intercropping system showed lower values at 104 and 132 DAP compared to guinea grass sole cropping. While there was 9 per cent increase in protein yield in guinea grass + maize intercropping at 75 DAP compared to sole cropping, it declined by 2 per cent at 104 DAP and 6 per cent at 132 DAP. It can be seen from Table 4 that guinea grass yield (2nd and 3rd cut) from maize intercropped plots was decreased causing depression effect on base crop. Though this did not decrease the fresh fodder yield it has affected the fodder quality in terms of total protein yield.

Sequential thinning of intercrops (maize and cowpea) did not result in any improvement on total protein yield from the system. It may be noted that the sequential thinning of intercrops did not change the total fodder yield from the cropping system and the possible reason has already been explained under the heading on total fresh fodder yield.

Among sole crop of maize and cowpea total protein yield was highest (836 kg/ha) with maize. This difference can be attributed to the differences on biomass productivity between maize and cowpea.

From the results presented above, it can be concluded that in terms of protein yield, guinea grass + cowpea cropping system ($C_4 + C_3$) is better than guinea grass + maize ($C_4 + C_4$) or guinea grass sole cropping.

6. Weed dry weight

Change in planting geometry of guinea grass did not influence the incidence of weeds. However, there was more probability for increased weed growth in paired row planting. This may be due to the increased free space available for weeds in paired row systems

Intercropping guinea grass with cowpea and maize caused considerable reduction in weed growth. The reduction was prominent with advancement of growth as well as with increase in the number of rows of intercrops in the intercropping system. This can be attributed to the smothering effects of intercrops on weed growth.

Under the intercropping system, the effect of cowpea and maize to check weed growth was more or less similar. However, a tendency of increased occurrence of weeds in maize intercropped plots were observed. This may be due to the difference in ground coverage by canopy between the maize and cowpea.

Sequential thinning of intercrops also did not influence the weed growth. Between the sole crops of maize and cowpea, weed growth was highest in maize than in cowpea. This may be due to the fact that maize is an erect and tall plant while cowpea is twining and covers the ground completely.

7. Uptake of nitrogen, phosphorus and potassium

Planting geometry did not influence the uptake of nitrogen, phosphorus and potassium (Tables 7,8 and 9) in guinea grass. The data on fodder yield in Table 2 and 3 explain this. Further, there was not much difference in the contents of nitrogen, phosphorus and potassium in guinea grass due to change in planting geometry.

Intercropping of guinea grass with maize and cowpea resulted in considerable increase in the uptake of nitrogen, phosphorus and potassium compared to sole cropping.

Patel *et al* (1968) reported that contents of nitrogen and phosphorus of fodder obtained from guinea grass + lucern intercropping was significantly higher than that from guinea grass sole crop. Similar increase in nitrogen content by 10-15 per cent in setaria + desmodium intercropping than setaria sole crop was reported by Thairu (1972). Chandini and Raghavan Pillai (1980) also reported that stylosanthes growing in the interspace of guinea grass has increased the nitrogen and phosphorus contents of intercropping system than solo crop of guinea grass. The result of the present study also agrees with the above findings. The data presented in Tables 2 and 3 revealed that there was marked increase in the fresh as well as dry fodder yield due to the intercropping compared to sole cropping.

Among the intercropping systems, uptake of nitrogen and potassium from the soil was highest from cropping system involving guinea grass + maize at 75 DAP. But potassium uptake was not affected due to intercropping at this stage.

When estimated at 104 DAP (coinciding with 2nd cut of guinea grass) there was not much difference in nitrogen, phosphorus and potassium uptake between the maize and cowpea intercropping system. But when estimated at 132 DAP (coinciding with 3rd cut of guinea grass), guinea grass + cowpea intercropping system has removed higher amounts of nitrogen, phosphorus and potassium compared to guinea grass + maize system. The higher nitrogen and potassium uptake at 75 DAP between guinea grass + maize and guinea grass + cowpea cropping systems can be attributed to their differential efficiency of biomass productivity between C_4 + C_4 and C_4 + C_3 intercropping systems. At 132 DAP, though their was not much difference in biomass productivity of C_4 and C_4 and C_4 + C_3 production systems, the percentage of contents of nitrogen, phosphorus and potassium were more in fodder obtained from guinea grass + cowpea (C_4 + C_3) intercropping system. Thus guinea grass + cowpea intercropping system removed more amounts of nitrogen, phosphorus and potassium than guinea grass + maize intercropping system at this stage.

Sequential thinning of intercrop did not result any change in nitrogen and potassium uptake in the cropping system. Total fodder production was not affected by sequential thinning as explained by the data presented in Tables 2 and 3.

Between sole crops of maize and cowpea, nitrogen, phosphorus and potassium uptake was highest in C_4 plant (maize) compared to C_3 plant (cowpea). This can be attributed to differences in the rate of photosynthesis, crop growth rate and biomass productivity between C_3 and C_4 plants.

8. <u>Organic carbon and total nitrogen contents of soil after the experiment</u>

The organic carbon and total nitrogen contents of soil were not affected due to change in planting geometry. But there was a decline in soil fertility in terms of organic carbon and total nitrogen due to guinea grass sole cropping (Table 12) as compared to pre-experimental soil nutrient status (Table 1).

Intercropping with maize and cowpea did not cause any considerable improvement in soil fertility compared to sole cropping of guino agrass. But between the two intercropping systems (guinea grass + maize and guinea grass + cowpea) there was improvement in soil fertility due to cowpea inter-cropping. Singh and Singh (1969), Sherman (1977) and Gillard (1977) have obtained similar increase in organic carbon and total nitrogen in grass + legume plots than pure grass plots. Chandini and Raghavan Pillai (1980) observed increase in total nitrogen and available phosphorus contents of soil in plots with guinea grass + stylosanthes than pure plots of guinea grass. Raghavan Pillai (1986) confirmed the above findings in guinea grass + stylosanthes and setaria grass + stylosanthes. The results of the present study also agree with the above findings.

It was further observed that while there was decline in organic carbon and total nitrogen contents of soil in maize intercropped plots, there was an improvement in soil fertility of cowpea intercropped plots. This trend was observed in plots of sole crops between maize and cowpea. Nair et al (1979) reported that available nitrogen and organic carbon contents of soil was slightly improved by growing cowpea. By growing cowpea in coconut garden, organic carbon content of soil was improved from 0.5 per cent to 0.7 per cent (Ramanagowda 1981). Mercy (1981) got decline in total nitrogen content of soil by growing fodder maize. The above findings also agree with the results of the present study. The effect of leguminous crops like cowpea to enrich the soil by nitrogen fixation is well known. Maize being a quick growing plant and heavy feeder of nutrients the soil depletion was higher.

Sequential thinning of intercrops (maize and cowpea) did not influence the post harvest soil fertility.

Based on protein yield and post harvest soil fertility it can be concluded that guinea grass + cowpea (C_4 + C_3) intercropping system are more suitable than guinea grass + maize (C_4 + C_4) intercropping system.

9. Economics

Net income was not affected due to change in planting geometry. Intercropping with maize or cowpea increased net income compared to guinea grass sole cropping. Krishnaraj et al (1979) reported that guinea grass + cowpea intercropping was more economical than guinea grass sole cropping. Chandini and Raghavan Pillai (1980) reported that guinea grass + stylosanthes intercropping system was found profitable than guinea grass sole crop agreeing with the results of the present study.

Among the intercropping systems, the highest cost-benefit ratio (1.557) and net income (Rs.3044/ha) were obtained from cropping system involving 2 rows of maize planted in between normal row of guinea grass (60 x 30 cm) (T_3) and the net return obtained from this cropping system was similar to that of T_4 (guinea grass paired row 30 x 30/90c + 4 rows of maize and T_8 (guinea grass paired row 30 x 30/90 c + 6 rows of cowpea). It may be noted that fodder production from these cropping system were also more or less the same (Table 2).

Sequential thinning of intercrops of maize and cowpea did not change the net income from the cropping system. Total fodder production due to sequential thinning also remained unchanged. Between the sole crops of maize and cowpea, cost-benefit ratio (1.74) and net return were the highest with maize (Rs.1955/ha). This can be attributed to the difference in fodder production between maize and cowpea. From the results and discussion presented so far, the following conclusion can be drawn.

Among the guinea grass based cropping systems tested, T_3 (guinea grass 60 x 30 cm + 2 rows of maize), T_4(guinea grass 30 x 30/90 cm + 4 rows of maize) and T_8 (guinea grass 30 x 30/90 cm + 6 rows of cowpea) are the most efficient and economic cropping systems. Among the three, T_8(guinea grass 30 x 30/90 cm + 6 rows of cowpea) can be identified as the best as it can also increased the protein yield and improve the fertility status of the soil in addition to its ability to produce higher amounts of fodder.

FUTURE LINE OF WORK

The study indicates the scope for increasing biomass productivity of a forage crop based cropping system by the paired row planting and intercropping. Sequential thinning of intercrops in the present study did not result any improvement in the total fodder production when nutrient supply was limited to the requirement of base crop alone. Therefore, it is suggested that further work may be initiated in this line involving paired row planting of base crop, sequential thinning of intercrops and varying levels of nutrients.

SUMMARY

SUMMARY

An investigation was carried out at the Instructional farm attached to the College of Agriculture, Vellayani during 1987 to study the biomass productivity of guinea grass based cropping system involving C_3 and C_4 plants. There were 12 treatments involving normal (60 x 30 cm) and paired row (30 x 30/90 cm) planted guinea grass, sole crops of maize and cowpea and different rows of maize and cowpea as intercrops in the interspace of guinea grass with and without sequential thinning. The experiment was laid out in Randomised Block Design with three replications. The results of the study are summarised below:-

1. Change in planting geometry from normal (60 x 30 cm) to paired row (30 x 30/90 cm) did not alter the fresh and dry fodder yield of guinea grass.
2. Intercropping in guinea grass with maize and cowpea increased total fresh and dry fodder yield and net returns compared to guinea grass sole cropping.
3. Among guinea grass based cropping systems tested, the following are found to be efficient and economic cropping system.

(a) 2 rows of maize grown in the interspace of normal row (60 x 30 cm) planted guinea grass.

(b) 4 rows of maize grown in the interspace of paired row (30 x 30/90 cm) planted guinea grass.

(c) 6 rows of cowpea grown in the interspace of paired row (30 x 30/90 cm) planted guinea grass.

4. Both maize and cowpea were found suitable as intercrops in guinea grass to increase the total fodder production.

5. Sequential thinning of intercrops (maize and cowpea) did not increase the total fodder production in guinea grass based cropping system when nutrient supply was limited to the requirement of base crop. The leaf-stem ratio and protein yield of the fodder, incidence of weed, nutrient uptake (Nitrogen, Phosphorus and Potassium), post harvest soil fertility and net income were remained unaffected due to sequential thinning of the intercrops of maize and cowpea.

6. Of the two sole crops maize and cowpea, maize was found to be the best in terms of fodder yield, protein yield and net income. The uptake of nutrients

(Nitrogen, Phosphorus and Potassium) and incidence of weeds were more with maize than with cowpea. But leaf-stem ratio of fodder was higher with cowpea than with maize. The post harvest soil fertility status was improved in plots with cowpea whereas the effect of maize was to decrease the fertility status of the soil.

7. A change in planting geometry of guinea grass did not effect the leaf-stem ratio and the protein yield of fodder, nutrient uptake (Nitrogen, phosphorus and potassium) by the plant, incidence of weeds and post harvest soil fertility. Net income from guinea grass was also not affected by changing the planting geometry.

8. The leaf-stem ratio of fodder was influenced by intercropping and the leaf-stem ratio of fodder obtained from guinea grass + cowpea intercropping was higher as compared to guinea grass + maize intercropping.

9. Intercropping in guinea grass increased the total protein yield and guinea grass + cowpea intercropping yielded greater quantity of protein from fodder. It was observed that cropping system involving 6 rows of cowpea grown in the interspace of paired

row (30 x 30/90 cm) planted guinea grass was the best in terms of quantity and quality of the fodder.

10. Intercropping in guinea grass with maize and cowpea decreased the incidence of weeds and increased the nutrients uptake. Among the intercropping systems, nitrogen, phosphorus and potassium removal was the highest in guinea grass + cowpea when compared to guinea grass + maize intercropping system.

11. There was improvement in the post harvest soil fertility due to guinea grass + cowpea intercropping as compared to guinea grass + maize intercropping system.

Taking into consideration the total fodder production, fodder quality, post harvest soil fertility and economics, it can be construed that a guinea grass based cropping system involving six rows of cowpea grown as the intercrop in the paired row planted guinea grass (30 x 30/90 cm) is ideal. In other words a forage crop based cropping system involving a C_4 grass + C_3 legume would be more appropriate.

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* Originals not seen.

APPENDICES

APPENDIX I

Weather data during crop period (25 to 44th standard Meteorological week)

Standard weeks	Period	Rainfall (mm)	Temperature (°C)		Relative humidity (mean)
			Maximum	Minimum	
25	June 18 - 24	15.6	30.88	24.63	77
26	" 26 - July 1	65.7	30.29	24.42	79
27	July 2 - 8	7.6	30.51	23.55	77
28	" 9 - 15	4.3	30.95	24.27	79
29	" 16 - 22	0.8	31.64	24.71	74
30	" 23 - 29	-	32.02	24.87	71
31	" 30 - Aug.5	35.2	31.32	24.22	79
32	Aug. 6 - 12	-	31.00	23.82	73
33	" 13 - 19	126.9	29.87	22.87	83
34	" 20 - 26	84.1	29.90	22.97	84
35	" 27 - Sept.2	27.1	30.25	24.08	86
36	Sept.3 - 9	-	31.27	24.20	81
37	" 10 - 16	6.5	32.38	24.83	79
38	" 17 - 23	71.8	30.80	23.88	72
39	" 24 - 30	47.7	30.70	23.52	82
40	Oct. 1 - 7	114.8	30.75	23.57	79
41	" 8 - 14	45.2	31.00	24.09	82
42	" 15 - 21	56.6	30.46	24.00	83
43	" 22 - 28	30.5	30.19	24.50	83
44	" 29 - Nov.4	56.2	30.71	23.81	83

APPENDIX II a

Abstract of analysis of variance for total fresh fodder yield, total dry fodder yield and total protein yield from the system.

Source	df	Mean sum of square								
		Total fresh fodder yield from the system(t/ha)			Total dry fodder yield from the system (t/ha)			Total protein yield from the system (kg/ha)		
		At 75 DAP	At 104 DAP	At 132 DAP	At 75 DAP	At 104 DAP	At 132 DAP	At 75 DAP	At 104 DAP	At 132 DAP
Block	2	44.000**	153.576**	144.064**	2.419**	14.805**	15.641**	53206*	345707**	662062**
Treatment	11	60.240**	124.789**	385.334**	7.673**	11.360**	32.348**	80392**	132026**	672898**
Error	22	4.104	7.372	12.246	0.460	1.113	1.679	11520	35946	41229

APPENDIX II b

Abstract of analysis of variance for Leaf-stem ratio, weed dry weight and nitrogen uptake from the system.

Source	df	Mean sum of square							
		Leaf - stem ratio			Weed dry weight		Nitrogen uptake from the system (kg/ha)		
		At 75 DAP	At 104 DAP	At 132 DAP	At 3 WAP	At 6 WAP	At 75 DAP	At 104 DAP	At 132 DAP
Block	2	0.020	0.038	0.041	612.184	93.771	1448**	10523**	16786**
Treatment	11	0.577**	0.457**	0.578**	3010.525**	718.652**	1965**	3227**	19196**
Error	22	0.030	0.018	0.015	381.384	166.282	294	760	968

** Significant at 1% level   * Significant at 5% level

APPENDIX III a

Abstract of analysis of variance for phosphorus and potassium uptake from the system, Soil organic carbon and soil total nitrogen after the experiment.

Source	df	Mean sum of square							
		Phosphorus uptake from the system (kg/ha)			Potassium uptake from the system (kg/ha)			Soil organic carbon after after experi ment (t/ha)	Soil total nitrogen after experi ment (t/ha)
		At 75 DAP	At 104 DAP	At 132 DAP	At 75 DAP	At 104 DAP	At 132 DAP		
Block	2	43.244**	343.702**	485.012**	1088*	4422**	5057**	33.373**	0.355**
Treatment	11	19.139**	86.864**	405.786**	1273**	2094**	5713**	5.123**	0.076**
Error	22	3.162	11.177	19.521	248	468	646	1.245	0.016

APPENDIX III b

Abstract of analysis of variance of Net profit and Benefit cost ratio from the system

Source	df	Mean sum of square	
		Net profit	Benefit cost ratio
Block	2	1811000**	0.1749**
Treatment	11	2742727**	0.07999**
Error	22	135181	0.01192

** Significant at 1% level

* Significant at 5% level

BIOMASS PRODUCTIVITY OF A FORAGE CROP BASED CROPPING SYSTEM INVOLVING C_3 AND C_4 PLANTS

BY
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ABSTRACT OF A THESIS
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ABSTRACT

An investigation was undertaken at the College of Agriculture, Vellayani during 1987 to study the biomass productivity of guinea grass based cropping system involving C_3 and C_4 plants. The intercrops were a C_4 grass maize and a C_3 legume-cowpea. The intercrops were grown in different rows with and without sequential thinning. The experiment was laid out in Randomised Block Design with three replications. After harvesting intercrops guinea grass was allowed to grow without subsequent intercrops. Total biomass yields upto third cut of guinea grass were subjected to evaluation. The Abstract of the study is presented below:-

1. Change in planting geometry of guinea grass from normal (60 x 30 cm) to paired row (30 x 30/90 cm) did not make any change in the fodder yield and fodder quality.

2. Intercropping guinea grass with maize and cowpea increased the total fodder yield and protein yield compared to guinea grass sole cropping.

3. Maize a C_4 grass and cowpea a C_3 legume were found to be suitable intercrops in guinea grass (a C_4 perennial grass) to increase the total fodder and protein yield compared to guinea grass sole cropping.

4. Sequential thinning of intercrops (maize and cowpea) did not increase the total fodder production from guinea grass based cropping system when nutrient supply was limited to the requirement of base crop.

5. Among the guinea grass based cropping system tested the following three are found to be efficient and economic.

   (a) Two rows of maize as intercrop grown in the interspace of normally planted (60 x 30cm) guinea grass.

   (b) Four rows of maize as intercrop grown in the interspace of paired row (30 x 30/90 cm) planted guinea grass.

   (c) Six rows of cowpea as intercrop grown in the interspace of paired row (30 x 30/90 cm) planted guinea grass.

6. Considering the fodder production, fodder quality, post harvest, soil fertility and net income a forage based cropping system involving six rows of cowpea grown in the interspace of paired row (30 x 30/90 cm) planted guinea grass would be the ideal. In other words a forage crop based cropping system involving a C_4 grass + C_3 legume would be the best.