INTENSIVE FODDER PRODUCTION UNDER IRRIGATED CONDITION IN PARTIAL SHADE

By

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DECLARATION

I hereby declare that this thesis entitled "Intensive fodder production under irrigated condition in partial shade" 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 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 "Intensive fodder production under irrigated condition in partial shade" is a record of research work done independently by Ms. Romy Jacob under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ABBREVIATIONS USED IN THIS THESIS

@	-	At the rate of
°C	-	Degree celsius
Ca	-	Calcium
cc	-	Cubic centimetre
cm	-	Centimetre
CPE	-	Cumulative pan evaporation
Fig.	-	Figure
FYM	-	Farm yard manure
g	-	Gram
ha	-	Hectare
K	-	Potassium
Kg	-	Kilogram
LAI	-	Leaf area index
m	-	Metre
Mg	-	Magnesium
mm	-	Millimetre
N	-	Nitrogen
P	-	Phosphorus
y	-	Year

INTRODUCTION

1. INTRODUCTION

India has the largest cattle population in the world, but, the milk production potential of cattle is very low in our country. The farm animals are forced to subsist on dry stalks and straws during lean periods (November - May), which are poor in nutrients. Thus the animals are literally starved and they fail to express their full genetic potential. The gap between the demand and supply of forage crops is very wide. The fodder resources of our country are hardly sufficient for feeding even half of the existing number of cattle. In India, less than two per cent of the arable land is utilized for cultivation of forage crops due to increased pressure from food and cash crops. Except for maize and sorghum grown in some parts of Punjab, Uttar Pradesh., Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka, crops are not generally grown specifically for fodder purpose Suitable fodder species identified for potential production in various agroclimatic regions are also less.

The scenario is not different in Kerala also. According to the 1996 cattle census, the population of cattle in the state is 35.6 lakh heads, for the feeding of which 67.6 lakh tonnes of dry roughage is required every year. The dry roughage production in the state is only 40 lakh tonnes; the deficit being 27.6 lakh tonnes per year (nearly 40 per cent of the requirement). Cultivated fodders constitute only 3.4 percentage of total dry roughage in the state. This is mainly due to the fact that the area set apart for fodder cultivation is very meagre. Also, the grazing lands are gradually dwindling, owing to competition from food crops, overgrazing and alarmingly high denudation of available grass lands. Our state is woefully lacking in the production of green fodder, without which the full potential of milk production from the cross-bred cattle can not be achieved. Presently, 75 per cent of cattle population in Kerala is cross-bred, but, their average milk production is only 5.2 kg per day as against the average potential production of 10 kg per day.

Fodder is not yet recognised as an agricultural crop in the state. The farmers are reluctant to set apart any significant portion of their land for fodder cultivation. Even the dairy farmers do not insist on growing fodder crops to feed their cattle. This has lead to the increased use of concentrated and artificial feeds for feeding cattle which in turn resulted in high cost of milk production in the state. By including sufficient quantities of green fodder in animal diet, the cost of feeding can be reduced by 50 per cent. In addition, green fodder is rich in minerals and other nutrients required for the dairy animals. It improves the quality and quantity of milk, enhances rapid growth of calves, imparts disease resistance and helps the animals to express their full genetic potential.

The scope for bringing additional land under fodder cultivation is limited in Kerala, due to various socio-economic reasons and utilization of arable lands for agricultural and non-agricultural purposes. The only practical way to attain self sufficiency in green fodder production is to modify the existing cropping systems by including fodder as a component or complementary crop. Ninety five per cent of our cattle population is in villages. Intercropping of fodder under the canopy of trees will be a possible way to intensify fodder production in such areas. Fodder intercropping in coconut gardens attains great importance in this context. To bridge the deficit in fodder production, out of the total area of 7.5 lakh ha under coconut in the state, 1.2 lakh ha is to be brought under fodder intercropping. In a scientifically planted coconut garden, nearly 77 per cent of the land area is unexplored by the roots of coconut palms. This area can be effectively utilized for fodder intercropping. Coconut palms also allow the infiltration of sufficient sunlight through their canopy for the growth of intercrops.

Several grass and legume fodders have been found to be suitable for intercropping, among which Congosignal (*Brachiaria ruziziensis*) is recognized to be highly adapted to the agroclimate of the state. It is palatable and nutritious to the livestock. The grass is also recommended for soil conservation and for improving the soil conditions for plant growth.

There is an urgent need for evolving superior agrotechniques for integrating fodder crops in the present cropping system so as to intensify the green fodder production in the state. Keeping this in view the present study entitled "Intensive fodder production under irrigated condition in partial shade" was conducted with the following objectives.

1. To study the effect of farm yard manure on the yield and quality of Congosignal grass grown under partial shade.
2. To study the effect of chemical fertilizers on the yield and quality of Congosignal.
3. To study the influence of irrigation on the yield and quality of Congosignal.
4. To assess the changes in physico-chemical properties of the soil due to grass cropping and
5. To work out the economics of irrigated fodder production in coconut gardens.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Congosignal (ruzi grass *Brachiaria ruziziensis* Germain and Evrard) is a palatable and nutritious fodder crop widely grown in Kerala (Nair, 1979). The grass has been identified to be shade tolerant and highly adapted for use in pastures under coconut plantations (Whiteman, 1980). The present investigation entitled "Intensive fodder production under irrigated condition in partial shade" envisaged the management of irrigation and organic manures as well as chemical fertilizers in congosignal grass grown as an intercrop in coconut garden. A review of literature, pertaining to the present study are briefed here :

2.1 Growth parameters and yield

2.1.1 Plant height

A study on some morphological characters of sudan grass (*Sorghum sudanens*) showed that plant height was significantly increased by the application of higher doses of nitrogen fertilizers (Abdel-Raouf *et al.*, 1967). Increase in plant height by higher inputs of nitrogen was reported in bahia grass (*Paspalum notatum*) by Beaty *et al.* (1977). In an experiment involving six forage grasses viz., *Brachiaria brizantha, B. miliiformis, Digitaria decumbens, Panicum maximum, Pennisetum clandestinum* and *P. purpureum*; the sward height was found to be bearing a positive correlation with nitrogen doses in the range 0-365 kg N ha^{-1} y^{-1}, in all the species (Eriksen and Whitney, 1981). Rai and Sankaranarayanan (1981) reported that plant height remained unaffected by phosphorus application in black anjan grass (*Cenchrus setigerus*). Nitrogen increased the plant height of anjan grass (*Cenchrus ciliaris*) when applied in combination with phosphorus and farm yard manure (FYM). Increase in plant height was observed upto 30 kg N ha^{-1} (Bhati and Mathur, 1984). In a field study with hybrid napier involving four levels of fertilizer nitrogen (250, 500, 750 and 1000 kg N ha^{-1} y^{-1}); two levels of potassium (150 and 300 kg K_2O ha^{-1} y^{-1}) and one level of phosphorus (200 kg P_2O_5 ha^{-1} y^{-1}) indicated that N rate was positively correlated with plant height (Yeh, 1988). A similar trend was observed in dwarf napier grass also when varying levels of N and K were tested along with a fixed level of P (Hong and Hsu, 1993). Potash application did not show any significant effect on height of teosinte (*Euchlaena mexicana*) (Thakuria, 1993).

2.1.2 Tiller number $hill^{-1}$

Koblet *et al.* (1969) experimentally proved the importance of nitrogen in the regulation of tillering in grasses. Increased doses of nitrogen from zero to 120 kg ha^{-1} y^{-1} markedly increased the tiller production. Similar results were also obtained by Skripko (1971). Application of high nitrogen at all stages of growth was found to be increasing the tiller number per clump of bahia grass (Beaty *et al.*, 1977). In an experiment conducted to study the effect of N, P and FYM on the forage and nutritive value of *Cenchrus ciliaris*, number of tillers increased with increased doses of nitrogen. The response to nitrogen was significant only upto 30 kg N ha^{-1} (Bhati and Mathur, 1984). Reddy (1990) also observed an increase in the number of tillers of hybrid napier with increased nitrogen levels. Krishnan (1993) working on guinea grass reported that phosphorus and potassic fertilizers did not influence tiller production in guinea grass.

2.1.3 Leaf : stem ratio

Yeh (1988) reported that nitrogen rate had little or no effect on the leaf : stem ratio of hybrid napier. Potassium rates also had no effect on the leaf : stem ratio. Williams and Hanna (1995) found a negative correlation between leaf : stem ratio and dry matter yield.

2.1.4 Leaf Area Index (LAI)

Leaf area of maize (*Zea mays*) was significantly increased with the annual application of 35 t FYM ha^{-1} (Hussein, 1969). Munegowda *et al.* (1989) reported that the number of leaves and LAI in hybrid napier was maximum at 150 kg N ha^{-1} when compared to grass grown without nitrogen. Singh and Chatterjee (1968) observed that maximum LAI of four was attained in thin napier grass (*Pennisetum polystachyon*) with high nitrogen application. Evans and Wardlaw (1976) experimentally proved that maximum light interception in cereal crops occurred at LAI of four and further increase in LAI had little effect on photosynthesis. In a field experiment with dinanath grass (*Pennisetum pedicellatum*), Das and Chatterjee (1976) observed that 95 per cent of light interception occurred at a LAI of 7.5. Beaty *et al.* (1977) recorded an increase in the number of leaves per stolon and hence a high LAI with increase in N rates from 0 - 356 kg ha^{-1} in bahia grass.

2.1.5 Green fodder yield

Irrigation was found to increase the green matter yield of maize by 14.65 t ha^{-1} over the unirrigated crop (Vanek, 1974). In Jaragua grass

(*Hyparrhenia rufa*) irrigation increased the herbage yield by 31 per cent compared to the unirrigated treatment (Filho, 1977). The crop was irrigated at 100 per cent of pan evaporation. Irrigation did not decrease the seasonal variation in yield. In both irrigated and unirrigated plots 74 per cent yield was obtained during summer. In an experiment conducted in East Siberia, irrigation at 70 per cent field capacity was found to increase the fresh fodder yield of meadow fescue (*Agropyron fibrosum*) significantly (Tarmaev, 1977). Filho (1978) studied the effect of summer and winter irrigation in *Brachiaria decumbens* and observed that average annual fresh matter yield was 18.8 kg per plant with irrigation and 14.7 kg per plant without irrigation. Irrigation did not improve the distribution of yield during the year, as of the total annual fresh matter yield about 71 per cent was produced in summer without irrigation and 75.6 per cent with irrigation. Forage production of oats (*Avena sativa*) was significantly increased by irrigation at 60 mm CPE (Gill and Malik, 1983). In an experiment conducted by Segui *et al.* (1984) in Cuba, the correlation between yield and irrigation was tested in 100 cultivars of guinea grass (*Panicum maximum*). The crop was grown under two moisture regimes viz., irrigated and rainfed. No remarkable yield differences was found between irrigated and rainfed treatments. Contrasting results were obtained by Khistaria *et al.* (1991) in fodder sorghum. Significantly higher fodder yields were obtained in irrigated treatments than the unirrigated control. Srivastava and Bhatnagar (1995) noted that in Uttar Pradesh hills a single irrigation of 50 mm during April-May boosted the yield of pastures by 45.32 per cent. The yield was improved by 101 per cent when the irrigation depth was 200 mm.

In North Sudan, fodder sorghum was found to give positive response to nitrogen fertilizers under irrigated conditions. Green fodder yield was increased upto 175 kg applied N ha^{-1} (Younis and Agabawi, 1967). Abichandani *et al.* (1971) reported that nitrogen application upto 60 kg N ha^{-1}, dressed after each cut increased the green forage yield of next cut remarkably in M. P. Chari cultivar of fodder sorghum. Increase in green fodder yield of sorghum was reported to be significant upto a nitrogen level of 90 kg ha^{-1} by Rabago and Rodriguez (1976). Armero and Cueva (1977) experimentally proved that fodder sorghum showed a still higher response to applied nitrogen. Highest fodder yield of 116.96 t ha^{-1} was recorded at 150 kg applied N ha^{-1}. Contradictory results were obtained by Vega and Martinez (1979). They found that nitrogen application did not cause any significant change in green fodder yield of sorghum. N and P fertilizers together with FYM were found to be increasing the fodder yield of *Cenchrus ciliaris* (Bhati and Mathur, 1984). Highest green matter yield was obtained in perennial grasses with the combined application of 50 t ha^{-1} FYM and 40 kg ha^{-1} each of N, P_2O_5 and K_2O (Sinyavoskii, 1986). A dose of 180 - 120 - 80 kg N - P_2O_5 - K_2O ha^{-1} was found to be optimum for maximum fresh fodder yield of hybrid napier (Krishnamurthy *et al.*, 1987). In an experiment with fodder sorghum, increasing N rates from zero to 150 kg ha^{-1} was found to boost the mean yield of fresh fodder from 16.15 t ha^{-1} to 22.50 t ha^{-1} (Baijvade *et al.*, 1988). Effect of nitrogen doses on fresh fodder yield of *Pennisetum purpureum* and *Brachiaria* spp. was studied by Mora and Rodiles (1989). The results indicated that nitrogen applied @ 276 kg ha^{-1} y^{-1} in four splits increased the fresh fodder yield of *Pennisetum purpureum* by 3.62 t and that of *Brachiaria* spp. by 1.97 t ha^{-1} over the control treatments. Dwivedi *et al.* (1991) observed a significant increase in the herbage production of thin napier grass with higher doses of nitrogen and phosphorus. Apart from the chemical fertilizers, FYM was also reported to be increasing the forage yield in grasses (Verma, 1991). Application of 10 t ha^{-1} FYM was found to be remarkably increasing the stover yield of maize. In congosignal significant increase in green fodder yield was observed by the application of 100 kg N ha^{-1} over 50 kg N ha^{-1}. Beyond 100 kg N ha^{-1}, the yield increase was non-significant (Meerabai *et al.*, 1992). FYM @ 10 t ha^{-1} along with N and P fertilizers improved the growth and forage yield of maize (Negi *et al.*, 1992). In red loam soils of Vellayani, Kerala, *Brachiaria ruziziensis* showed a green fodder yield increase upto fertilizer levels of 30 kg ha^{-1} P_2O_5 and 90 kg ha^{-1} K_2O (Meerabai *et al.*, 1993). Fertilizer nitrogen alone was found to be increasing the fodder yield of sorghum (Subbareddy *et al.*, 1993). Thakuria (1993) found that nitrogen, upto 90 kg ha^{1}, significantly improved the green fodder yield (upto 93.7 per cent) in teosinte (*Euchlaena mexicana*), but potassium levels had no significant effect on green fodder yield. According to the reports of Vasanthi *et al.* (1998), 10 t ha^{-1} of organic manure along with the recommended doses of N, P and K were necessary to obtain maximum herbage yield from fodder maize, sorghum and pearl millet.

2.1.6 Dry fodder yield

Irrigation @ 90 per cent field capacity was found to increase the dry matter yield of tropical pastures by 37 per cent (Herrera *et al.*, 1985). In

Setaria sphacelata, highest annual dry matter yield was obtained when grown under irrigated conditions. Dry fodder yields were high at 50 mm CPE and 100 mm CPE irrigation levels (Muldoon, 1986). Mansfield *et al.* (1990) also reported the enhancement of dry fodder yields by irrigation in perennial grasses. Irrigation during drier spring period increased the dry matter yield of perennial grasses by 109 per cent, but, irrigation during cool dry period had little effect on dry matter yield.

FYM @ 10.0 t ha^{-1} alone (without chemical fertilizers) increased the dry fodder yield in *Brachiaria ruziziensis* upto the third year of cultivation (Sharma *et al.*, 1992). In maize also, dry matter yield was found to increase with the application of organic manures. Optimum yield was obtained with the incorporation of 20 t FYM ha^{-1} (Balsaraf and Mohite, 1994).

In an experiment with fodder sorghum, application of 150 kg N ha^{-1} recorded the maximum dry matter yield (Gupta and Gupta, 1976). Para grass (*Brachiaria mutica*) also produced high dry matter with increased doses of nitrogen, eventhough the dry fodder yield per kilogram of nitrogen applied decreased at high levels of nitrogen (Chadhokar, 1978). Eriksen and Whitney (1981) reported a decrease in dry matter yield in *Brachiaria brizantha, B. miliformis* and *Panicum maximum* with nitrogen application when grown under shaded condition. Economic optimum level of P for maximum dry matter production in *Brachiaria decumbens* was found to be 240 kg P_2O_5 ha^{-1} (Echeverria *et al.*, 1982). Goncalves and Oliveira (1984) reported that P application @ 50 kg ha^{-1} increased the mean total dry matter yields of *Hyparrhenia rufa, Andropogon gayanus, Brachiaria humidicola, Brachiaria decumbens, Paspalum* species and

Panicum maximum from 22.55 t ha^{-1} to 35.04 t ha^{-1}. Boyer and Roberge (1985) noted an increase in growth rate and dry matter yield in many tropical pasture species with increase in nitrogen application. Combined application of N, P and K fertilizers were found to increase the dry forage yield in *Brachiaria decumbens*. But, P alone did not increase the yield (Cautaruth *et al.*, 1985). Chandini *et al.* (1985) observed that P application did not influence the dry matter yields of *Panicum maximum*, *Brachiaria ruziziensis* and *Setaria* sp. Fernandes *et al.* (1985) observed an increase in dry matter yield of *Brachiaria decumbens* when high doses of nitrogen were given in the presence of K. From a field study in Bolivia, Vallejos (1986) arrived at the conclusion that P and K alone had no significant effect on increasing the dry matter yields of *Brachiaria decumbens*. But, it was found that nitrogen and N and K interactions were significant in increasing the dry matter yield. Increased nitrogen doses had a linear relation with dry matter yields in a study conducted with hybrid napier (Singh, 1987). Phosphorus application at the rate 60 kg ha^{-1} increased the average dry matter yields of hybrid napier from 16.8 t (without P) to 18.7 t ha^{-1} (Maiti *et al.*, 1988). In *Digitaria decumbens* and *Brachiaria mutica* dry matter yield responses were significant upto 60 kg N ha^{-1} (Tudsri and Sornprasitti, 1988). Negative results were obtained by Yeh (1988), where nitrogen rates decreased the dry matter yield. *Andropogon gayanus, Brachiaria humidicola, Brachiaria decumbens, Brachiaria ruziziensis* and *Panicum maximum* showed an increased response to P_2O_5 upto 100 kg ha^{-1}, with regard to the dry matter yields (Costa, 1989). In *Brachiaria brizantha*, dry matter production increased with P_2O_5 levels upto 100 kg ha^{-1} (Filho *et al.*, 1989).

Pamo (1991) reported that dry matter yields were increased greatly with nitrogen rates upto 80 kg N ha^{-1} in *Brachiaria ruziziensis*. In case of congosignal grass grown under coconuts, dry fodder yields increased significantly with the application of 100 kg N ha^{-1} over 50 kg N ha^{-1} beyond which the yield increase was non significant (Meerabai *et al.*, 1992). Dry matter yield of perennial rye grass (*Lolium perenne*) increased by 10 per cent with the application of P_2O_5 @ 100 kg ha^{-1} (Acuna and Wilman, 1993). Hong and Hsu (1993) reported that in dwarf napier grass, dry fodder yield increased upto 920 kg ha^{-1} of applied nitrogen. In *Brachiaria ruziziensis*, the dry matter yield increased by about 31.9 per cent with increased nitrogen levels (Andrade *et al.*, 1996). Contradictory results obtained by Ezenwa *et al.* (1996) showed that more dry matter was produced by *Brachiaria ruziziensis* without nitrogen fertilizers (1.8 t ha^{-1}) than with nitrogen fertilizers (0.2 t ha^{-1}) when grown in pure stand or mixtures under a mature oil palm canopy. Dry matter yields of perennial grass were found to be responding positively to the freshly available P in the soil, from the most recent P application (Paynter and Dampney, 1996).

2.2 Uptake studies

2.2.1 Uptake of nitrogen

With the increase in nitrogen fertilization, N content of sorghum herbage was found to be increasing (Johnson and Cumminis, 1967). Gupta and Gupta (1976) reported that application of 150 kg ha^{-1} nitrogen to sorghum cultivars increased the uptake of nitrogen by the plant, beyond which no further response was observed. Application of FYM was also found to be effective in increasing the plant uptake of nitrogen. In maize, higher plant nitrogen in herbage was the result of the application of 11.2 t ha^{-1} of FYM (Puranik *et al.*, 1978). Phosphorus application increased the uptake of nitrogen in dinanath grass (*Pennisetum pedicellatum*) owing to the increased root proliferation (Rathore and Vijayakumar, 1978). Irrigation and nitrogen fertilization were reported to increase the nitrogen uptake by pearl millet and maize (Katoria *et al.*, 1981). Nitrogen and phosphorus fertilizers along with FYM were found to be effective in increasing the nitrogen uptake in *Cenchrus ciliaris*. Significant response was noted upto 30 kg N ha^{-1} (Bhati and Mathur, 1984). A negative correlation between applied levels of nitrogen and plant nitrogen content was reported by Fernandes *et al.* (1985). Inorganic fertilizers and FYM increased the nitrogen uptake in *Brumus inermis* and *Agropyrun cristatum* (Holt and Zentner, 1985). Higher levels of applied nitrogen had a linear relationship with the herbage nitrogen content in hybrid napier also (Singh, 1987). In maize, combined application of FYM and recommended fertilizers increased the nitrogen uptake (Srinivasan, 1992). Enhancing effect of FYM on nitrogen uptake was also reported by Minhas and Sood (1994).

2.2.2 Uptake of phosphorus

Nitrogen and phosphorus fertilizers applied at the rate 30 kg each of N and P_2O_5 ha^{-1} significantly increased the P uptake in presence of FYM in *Cenchrus ciliaris* (Bhati and Mathur, 1984). Phosphorus uptake was reported to be increasing with the application of FYM and inorganic fertilizers in *Brumus inermis* and *Agropyron cristatum* (Holt and Zentner, 1985). P level in plant was observed to be diminishing with the increase in nitrogen levels, in the presence of potassium, for *Brachiaria decumbens* (Fernandes *et al.*, 1985). In an experiment to study the influence of irrigation on yield and quality of *Cynodon dactylon* and *Panicum maximum* Perez and Acosta (1986) noticed that frequent irrigations increased the phosphorus content of the fodder. Chellamuthu *et al.* (1987) proved that application of nitrogen either as FYM or as ammonium sulphate increased the P uptake by ragi straw. In a pot culture study with four *Brachiaria* spp., *B. ruziziensis* was found to be more responsive to P application and showed the highest P uptake (Comide, 1989). In fodder maize P uptake was improved by the application of chemical fertilizers along with 10 t ha^{-1} of FYM (Srinivasan, 1992). Minhas and Sood (1994) confirmed the enhancing effect of FYM on P uptakes in maize. In an experiment with *Brachiaria ruziziensis*, N and K application was found to decrease the forage P concentrations (Andrade *et al.*, 1996).

2.2.3 Uptake of potassium

Potassium content of forage was slightly increased by irrigation (Squires, 1971). Plant potassium content increased with increased application of N, P and K in pastures of *Brachiaria humidicola* (Steel and Whiteman, 1980). Increased potassium content in soil was found to improve its uptake in *Brachiaria decumbens* (Raij and Van Quaggio, 1984). Contradictory to this Fernandes *et al.* (1985) reported that in *Brachiaria decumbens* plant potassium content was decreased with the application of high K to soil. Nitrogen applied as FYM or ammonium sulphate was found to increase the potassium uptake and hence the potassium content in ragi straw (Chellamuthu *et al.*, 1987). Dampney (1992) reported that herbage potassium percentage increased with potash application regardless of the requirement for maximum economic yield. Similar observation was recorded in dwarf napier grass by Hong and Hsu (1993).

2.2.4 Uptake of calcium and magnesium

FYM and mineral nitrogen fertilizers were found to increase Ca and Mg uptake (Naik and Ballal, 1968). Mohd. Najib and Hassan (1985) also reported that FYM either alone or with inorganic fertilizers markedly increased the concentrations of Ca and Mg in *Panicum maximum* and *Pennisetum purpureum*. Perez and Acosta (1986) reported an increase in Ca content of *Cynodon dactylon* and *Panicum maximum* with frequent irrigation. According to Botrel *et al.* .(1990) forage Ca content was unaffected by nitrogen application in *Brachiaria brizantha* and *Brachiaria humidicola*. Herbage Mg percentage was found to be reduced by increased potash rates (Dampney, 1992). Nitrogen and potash applications were found to decrease the forage Ca concentrations in *Brachiaria ruziziensis* (Andrade *et al.*, 1996).

2.3 Soil physical properties

2.3.1 Bulk density

A favourable decrease in bulk density of soil was observed by high organic matter addition (Klute and Jacob, 1949). But, Gingrich and Stauffer (1955) observed no significant change in soil bulk density by the addition of manures, crop residues and fertilizers. Similar report was given by Manickam and Venkataramanan (1972). They recorded that bulk density of soil did not change significantly by long term use of manures and fertilizers under dry conditions. An investigation on soil properties of grasslands made Misra *et al.* (1982) to arrive at the conclusion that the bulk density of soil was improved by the cultivation of grasses in calcareous red sandy loam soil. Among the various soil properties studied, bulk density of soil had the highest positive correlation with yield. Ingelmo and Caudrado (1986) found that several grass species decreased the apparent density of soil, making it more favourable for crop growth. Verma (1991) reported an improvement in soil bulk density by the application of 10 t ha^{-1} of FYM in maize field.

2.3.2 Water holding capacity

Gingrich and Stauffer (1955) observed no significant change in soil moisture content by the application of manures, crop residues and fertilizers. Salter and Williams (1963) reported an increase in soil moisture retention by the addition of FYM to sandy loam soil. Combined application of fertilizers and FYM increased the water retention in alfisols (Acharya *et al.*, 1988). In maize fields Verma (1991) observed an increase in the soil water holding capacity by the application of 10 t ha^{-1} of FYM.

2.3.3 Porosity of soil

A significant improvement in the macroporosity of soil was observed by the continuous cultivation of grasses (Ingelmo and Caudrado, 1986). Improvement of soil porosity by fodder grass cultivation was confirmed by Verma (1991) by a field experiment with fodder maize.

2.4 Soil chemical properties

2.4.1 Organic carbon

Ruzigrass (*Brachiaria ruziziensis*) was found to be contributing more to the soil organic carbon by long term cultivation, than crops like *Cajanus cajan*, *Crotalaria juncea* and *Muccuna aterrima* (Silva *et al.*, 1997).

2.4.2 Available nitrogen

Available nitrogen content of soil was found to be increased with the application of FYM or compost (Singh and Jaiprakash, 1968). Maurya and Ghosh (1972) reported an improvement in the available nitrogen status of alluvial and calcareous soils by the addition of FYM along with phosphate. Gupta *et al.* (1988) observed an increase in the available nitrogen status of soil upto 52 days after FYM application. Available nitrogen content decreased thereafter. Available nitrogen content of dry land soils were significantly increased upto 132.5 kg ha^{-1} by the addition of FYM and urea (Bhanavase *et al.*, 1992). Shinde and Gowade (1992) noticed an increase in the available nitrogen status of soil by the application of 20 t ha^{-1} of FYM.

2.4.3 Available phosphorus

FYM was observed to increase the P availability in soils (Dalton *et al.*, 1952 ; Naik and Ballal, 1968). Singh and Jaiparkash (1968) confirmed that addition of FYM or compost to soil improved the P availability. Superiority of FYM over crop residues in improving available P status of soil was reported by

Debnath and Hajra (1972). In a field trial with maize, Chaudhury *et al.* (1981) observed an increase in P availability in soil due to the application of 60 kg P_2O_5 ha^{-1} had 15 t FYM ha^{-1}. Similar result was obtained by Krishnaswamy *et al.* (1984). Chellamuthu *et al.* (1988) reported that application of nitrogen as FYM or ammonium sulphate increased the P availability in soil significantly. In an experiment on wheat, Gupta *et al.* (1988) observed that available P in the soil was improved by FYM application upto 52 days. FYM and urea increased the available P content of soil in sorghum fields (Bhanavase *et al.*, 1992). Addition of 15 t ha^{-1} of FYM was found to increase the available P content of soil from 14 kg ha^{1} to 16 kg ha^{-1} (Shinde and Gowade, 1992). Muthuswamy *et al.* (1990) reported that there was a significant build up of available P in soil to the extent of 40.9 per cent with the combined use of inorganic phosphate and FYM in ragi - maize - cowpea sequence.

2.4.4 Available potassium

Organic manures helped in the release of mineral bound insoluble potassium, reduced K fixation and thus increased the available potassium content in the soil (Levin and Jaffe, 1947). Potassic fertilizers in combination with FYM increased the potassium availability in soil (Nagi *et al.*, 1981). Sharma and Arora (1988) noted that K availability in soil was higher in FYM treated plots than plots which received chemical potassic fertilizers. Addition of 15 t ha^{1} of FYM was found to increase the available K content in soil from 23.5 kg ha^{-1} to 25.8 kg ha^{-1} (Shinde and Gowade, 1992).

2.5 Quality studies

2.5.1 Crude protein content

Increased rates of nitrogen application increased the crude protein content of sudan grass (Abdel-Raouf *et al.*, 1967). Phosphorus application was not influencing the crude protein content of black anjan (*Cenchrus ciliaris*) (Bahl *et al.*, 1970). In fodder sorghum cultivars, increased nitrogen levels did not influence the crude protein content (Hedge and Relwani, 1974). Malkov *et al.* (1978) observed that in irrigated pastures of Brazil, application of nitrogen improved the crude protein content of the herbage. Phosphorus application was found to be ineffective in determining the crude protein content of elephant grass (*Pennisetum purpureum*) (Walmsley *et al.*, 1978). Inorganic fertilizers were found to enhance the nitrogen uptake and hence improve the crude protein content in *Cenchrus* spp. (Chauhan and Faroda, 1979). Black anjan showed a decreased crude protein content with increased N and P levels (Ravikumar *et al.*, 1979). Leshem and Wermke (1981) opined that low soil nitrogen lead to low protein content in plants. *Brachiaria ruziziensis,* when intercropped with legumes, did not show any increase in crude protein content by the application of phosphorus (Chandini *et al.*, 1982). Bhati and Mathur (1984) observed significant increase in crude protein content of *Cenchrus ciliaris* with the combined application of N, P and FYM. In fodder sorghum, crude protein content increased significantly with nitrogen fertilization (Khader *et al.*, 1985). The crude protein content of *Brachiaria mutica* was 3.16 to 3.45 per cent as revealed from the results of an investigation on forage quality (Pachauri and Nair, 1987). In Bajra-napier hybrid, the average crude protein ranged from 8.41 to 9.90 per cent at nitrogen levels of zero to 150 kg ha^{-1} (Govindaswamy and Manickam, 1988). Similar trend was observed in sorghum and sorghum x sudan grass cultivars (Raj and Patel, 1988), *Digitaria decumbens* and *Brachiaria mutica* (Tudsri and Sornprasitti, 1988), hybrid napier (Yeh, 1988) and dwarf napier grass (Hong and Hsu, 1993). The average crude protein content of brazilian napier was reported to be 8.2 per cent by Devasena *et al.* (1993). Phosphorus application @ 20 kg P_2O_5 ha^{-1} and potassium @ 40 kg K_2O ha^{-1} were found to increase the crude protein content in teosinte (Thakuria, 1993). Nitrogen application was found to increase the crude protein yields of *Brachiaria ruziziensis*. The effect of potassium on crude protein content was nonsignificant (Andrade *et al.*, 1996).

2.5.2 Crude fibre content

Crude fibre content of *Brachiaria ruziziensis* was found to decrease with the application of phosphorus (Chandini *et al.*, 1982). Crude fibre content was found to increase with increased nitrogen application in fodder sorghum (Khader *et al.*, 1985). The neutral detergent fibre (NDF) content of *Brachiaria mutica* was found to be 68.04 to 79.92 per cent (Pachauri and Nair, 1987) and that of brazilian napier was 71.44 per cent (Devasena *et al.*, 1993).

2.5.3 K : (Ca + Mg) ratio

Kemp and t'Hart (1957) reported that the quality of fodder is decided greatly by K : (Ca + Mg) ratio. The K : (Ca + Mg) ratio has significant relationship with the incidence of grass tetany (Hypomagnesaemia) in cattle. The safe limit of K : (Ca + Mg) ratio was reported to be 2.2 (Grumes *et al.*, 1970). The critical K : (Ca + Mg) ratio of 2.2 was confirmed by Thill and George (1975).

Increased nitrogen application was found to be decreasing the K : (Ca + Mg) ratio in grasses (Khan and Ali, 1969). Mayland *et al.* (1975) found that increased nitrogen fertilizers improved the Ca and Mg concentration in forage and thus reduced the K : (Ca + Mg) ratio.

2.6 Soil moisture studies

2.6.1 Field water use efficiency

Water use of silage corn was found to be more under irrigated conditions when compared to unirrigated conditions. The crop utilized 0.31 cm and 0.47 cm water daily under unirrigated and irrigated conditions respectively (Doss *et al.*, 1970). In a field study with *Panicum maximum, Cenchrus ciliaris and Cynodon dactylon* x *Cynodon nlemfuensis*, water consumption during dry season was found to be increasing with irrigation. The water use of grasses were maximum from the 0 - 40 cm layer of soil (Herrera *et al.*, 1985). In fodder maize, maximum fresh forage yield was obtained by giving irrigation at 0.7 irrigation water : cumulative pan evaporation (IW : CPE) ratio. Yield was 4.9 and 28.8 per cent higher than the yields obtained with 0.5 IW : CPE irrigation and unirrigated treatments respectively. Water use efficiency was maximum with 0.7 IW : CPE irrigation treatment (Palled *et al.*, 1991).

2.6.2 Soil moisture depletion pattern

Morachan (1978) reported that water can move upwards sufficiently for use by crops from depths as much as 180 cm below root zone. In maize-cowpea and bajra-cowpea forage mixtures, soil moisture depletion from top 30 cm soil layer was increased with increase in water supply (Rana and Malik, 1981).

2.7 Root studies

Nitrogen fertilization significantly increased the root growth in grain sorghum (Warsi *et al.*, 1973). In elephant grass, increased nitrogen levels increased the root growth and root weight (Asis *et al.*, 1976). In a mixed prairie, wheat grass showed increased development of roots with increase in nitrogen levels (Lorenz, 1978). Too high levels of nitrogen in soil was found to restrict the root growth of crops (Hurd and Spartt, 1979).

2.8 Performance of fodder grasses under shade

Congosignal (*Brachiaria ruziziensis*) was reported to be a shade tolerant grass by Nair (1979). This grass was found to be suitable for cultivation under plantations in humid tropics (Chandini and Pillai, 1980). Gowda *et al.* (1985) observed that fodder yields of *Pennisetum polystachyon*, hybrid napier and *Panicum antidotale* were less under coconut gardens than in open fields, but, intercropping with high yielding fodder gave markedly higher economic returns. In a study conducted by Wong *et al.* (1985), Leaf Area Index, leaf : stem ratio and nitrogen content of grasses were found to be increasing and dry matter production and tillering to be decreasing by cultivation under shaded situation. Decrease in dry matter yield of grasses was also reported by Schreiner (1987). Shading intensities of 25, 50 and 80 per cent decreased the dry matter yields by 5.0, 41 and 78 per cent respectively. Meanwhile, the concentration of nitrogen in grasses increased with increased shading. Regrowth of fodder grasses after defoliation was found to be faster when grown under tree canopy than in open conditions (Belsky, 1994). Productivity was also found to be increasing with fertilizer application under shaded condition. *Panicum maximum* exhibited high water use efficiency and biomass accumulation in shaded condition (Kinyanario *et al.*, 1995).

2.9 Effect of fodder intercropping on coconut yield

Fodder intercropping was observed to be increasing the health and yield of coconut palms (Pillai, 1986). But, Watson (1986) found no significant effect on the coconut yield by fodder intercropping. Again, George (1996) noticed a favourable influence of the intercropped fodder on the nut yield of coconut.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken to evaluate the influence of FYM, chemical fertilizers and irrigation on the yield and quality of congosignal grass (*Brachiaria ruziziensis* Germain and Evrard) grown under partially shaded coconut garden, to assess the changes in physico-chemical properties of the soil due to grass cropping and also to work out the economics of grass cultivation. The materials used and methods adopted for the study are detailed below :

3.1 Experimental site

The experiment was conducted in the upland coconut gardens of the Instructional Farm of College of Agriculture, Vellayani, Thiruvananthapuram. The farm is located at 8.5^0 N latitude and 76.9^0 E longitude at an attitude of 29 m above mean sea level.

3.1.1 Climate and season

Wet tropical climate prevailed in the experimental location. The experiment was started in the month of July 1998 and continued upto June 1999. The data on meteorological parameters viz., minimum and maximum temperature, relative humidity, evaporation and rainfall collected during the crop period is furnished in appendix I and represented graphically in Fig. 3.1.

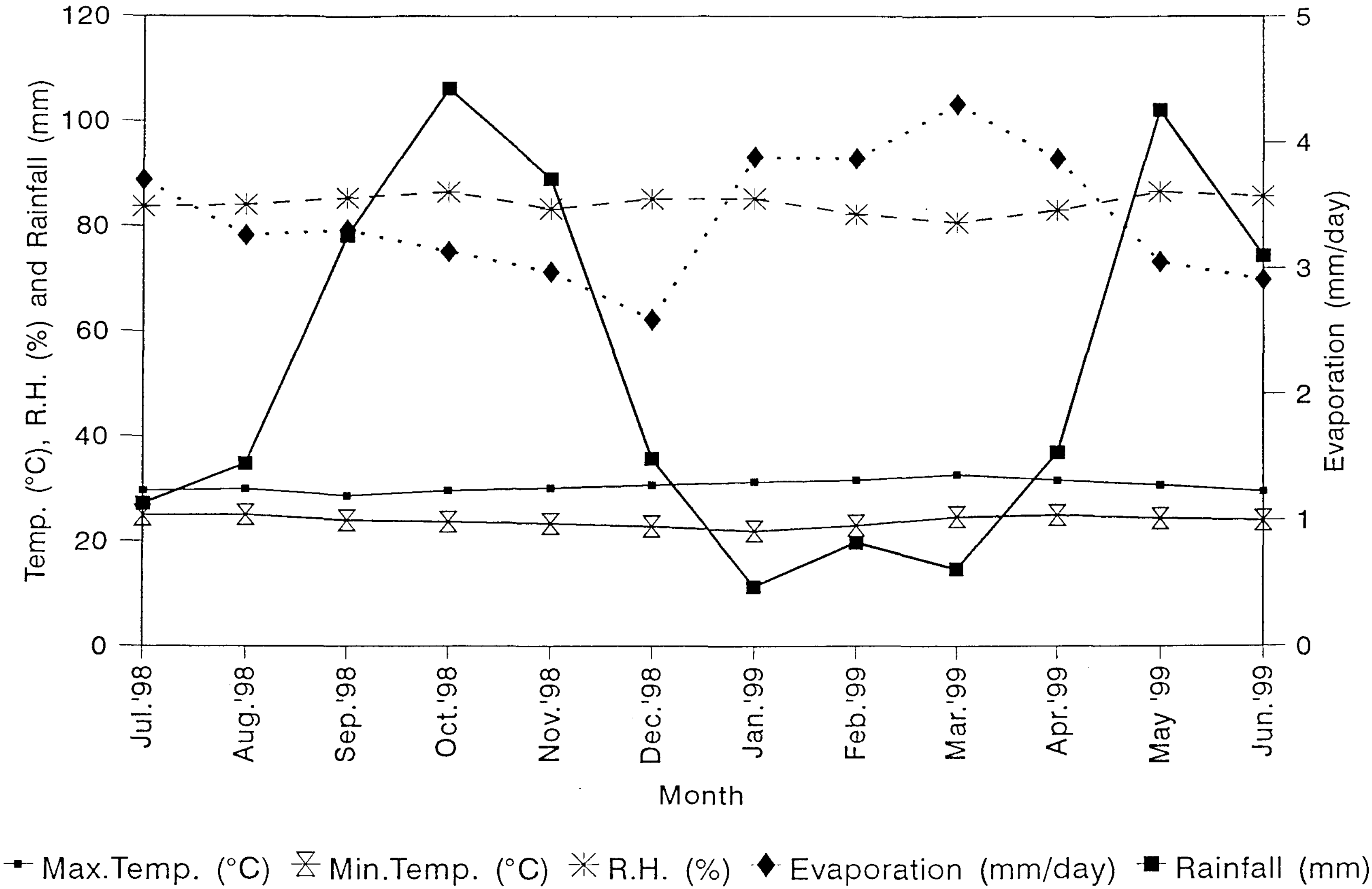


Fig. 3.1. Weather parameters during the crop period (July 1998 to June 1999)

3.1.2 Soil

The soil of the experimental site was red sandy clay loam (oxisol, Vellayani series).

Prior to the conduct of the experiment, composite soil samples were drawn from 0-15 cm depth and analysed for physico-chemical properties. The data obtained are given in Table 3.1. The soil was low in available nitrogen and potassium and medium in available phosphorus, with an acidic pH.

3.1.3 Cropping history of the experimental site

The experimental site was a partially shaded coconut garden with palms of 75 years of age permitting 70 per cent of the solar radiation to filter through the canopy. The interspaces of coconuts were lying fallow during the previous years.

3.2 Experimental procedure

3.2.1 Layout and design

Test crop : congosignal (*B. ruziziensis*)

Experimental design : 4 x 2 x 2 Factorial Experiment in RBD

Replications : 3

Spacing : 40 x 20 cm

Plot size

Gross plot size	: 3.6 x 3.0 m
Net plot size	: 2.0 x 2.2 m
Total number of plots	: 48

Table 3.1 Soil physico-chemical properties of the experimental site

	Particulars	Mean value	Method used
I	Physical properties		
	1. Mechanical composition		Bouyoucos Hydrometer method (Bouyoucos, 1962).
	Coarse sand	16.70 per cent	
	Fine sand	31.30 per cent	
	Silt	25.50 per cent	
	Clay	26.50 per cent	
	2. Bulk density (g cc^{-1})	1.375	Gupta and Dakshinamoorhti (1980).
	3. Water holding capacity (per cent)	21.50	Gupta and Dakshinamoorhti (1980).
	4. Porosity (per cent)	32.00	Gupta and Dakshinamoorhti (1980).
II	Chemical Properties		
	1. Soil reaction (pH)	5.1	Direct reading with pH meter in 1 : 2.5 soil suspension (Gupta and Dakshinamoorhti (1980).
	2. Organic carbon (per cent)	0.43	Walkely and Black's method (Jackson, 1973).
	3. Available nitrogen (kg ha^{-1})	193	Alkaline potassium permanganate method (Subbiah and Asija, 1956).
	4. Available P_2O_5 (kg ha^{-1})	47.3	Bray's colorimetric method (Jackshon, 1973).
	5. Available K_2O (kg ha^{-1})	94.8	Flame photometric method (Jackson, 1973).

Two rows of plants on all sides of each plot were left as border crops.

The layout of the experiment is given in Fig. 3.2. An overall view of the experimental site is shown in plate 1.

3.2.2 Treatments

A. Irrigation levels

a_1 - Irrigation at 30 mm CPE

a_2 - Irrigation at 45 mm CPE

a_3 - Irrigation at 60 mm CPE

a_4 - Rainfed

Depth of irrigation - 4 cm

B. Organic manure

b_1 - FYM 5.0 t ha^{-1}

b_2 - FYM 7.5 t ha^{-1}

C. Fertilizer

c_1 - 100 per cent of package of practices recommendation

c_2 - 50 per cent of package of practices recommendation

Note : Package of Practices Recommendations for congosignal are 150 : 50 : 50 kg NPK ha^{-1} and 5.0 t FYM ha^{-1}.

3.2.3 Treatment combinations

T_1 - $a_1 b_1 c_1$ - irrigation at 30 mm CPE + FYM 5.0 t ha^{-1} + 100 per cent of fertilizers

T_2 - $a_1 b_1 c_2$ - irrigation at 30 mm CPE + FYM 5.0 t ha^{-1} + 50 per cent of fertilizers

T_3 - $a_1 b_2 c_1$ - irrigation at 30 mm CPE + FYM 7.5 t ha^{-1} + 100 per cent of fertilizers

T_4 - $a_1 b_2 c_2$ - irrigation at 30 mm CPE + FYM 7.5 t ha^{-1} + 50 per cent of fertilizers

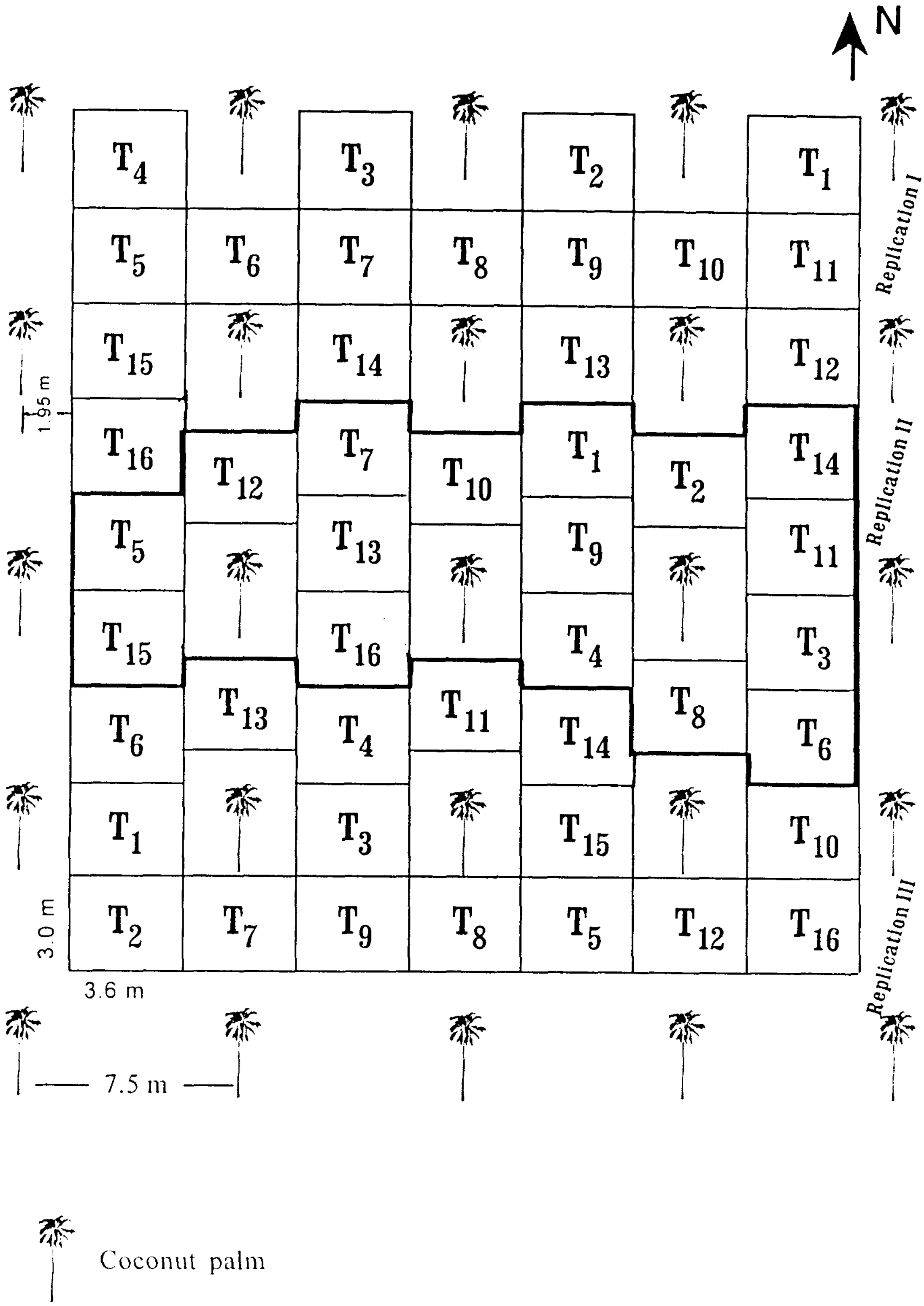


Fig. 3.2. Field layout of the experiment

Plate 1. Overall view of the experimental site

T_5 - a_2 b_1 c_1 - irrigation at 45 mm CPE + FYM 5.0 t ha^{-1} + 100 per cent of fertilizers

T_6 - a_2 b_1 c_2 - irrigation at 45 mm CPE + FYM 5.0 t ha^{-1} + 50 per cent of fertilizers

T_7 - a_2 b_2 c_1 - irrigation at 45 mm CPE + FYM 7.5 t ha^{-1} + 100 per cent of fertilizers

T_8 - a_2 b_2 c_2 - irrigation at 45 mm CPE + FYM 7.5 t ha^{-1} + 50 per cent of fertilizers

T_9 - a_3 b_1 c_1 - irrigation at 60 mm CPE + FYM 5.0 t ha^{-1} + 100 per cent of fertilizers

T_{10} - a_3 b_1 c_2 - irrigation at 60 mm CPE + FYM 5.0 t ha^{-1} + 50 per cent of fertilizers

T_{11} - a_3 b_2 c_1 - irrigation at 60 mm CPE + FYM 7.5 t ha^{-1} + 100 per cent of fertilizers

T_{12} - a_3 b_2 c_2 - irrigation at 60 mm CPE + FYM 7.5 t ha^{-1} + 50 per cent of fertilizers

T_{13} - a_4 b_1 c_1 - Rainfed + FYM 5.0 t ha^{-1} + 100 per cent of fertilizers

T_{14} - a_4 b_1 c_2 - Rainfed + FYM 5.0 t ha^{-1} + 50 per cent of fertilizers

T_{15} - a_4 b_2 c_1 - Rainfed + FYM 7.5 t ha^{-1} + 100 per cent of fertilizers

T_{16} - a_4 b_2 c_2 - Rainfed + FYM 7.5 t ha^{-1} + 50 per cent of fertilizers

3.2.4 Details of cultivation

3.2.4.1 Field preparation

With the onset of South-West monsoon, the experimental area was cleared off weeds, given two thorough diggings, stubbles were removed and the field was laid out into blocks and plots leaving an area of 1.95 m radius around the base of each palm. The plots were again dug and levelled.

3.2.4.2 Manuring and fertilizer application

Farm yard manure (0.4 per cent N, 0.3 per cent P_2O_5 and 0.2 per cent K_2O) was applied according to the treatments during the final preparation of land. Phosphorus and potash were given as mussoriphos (18 per cent P_2O_5)

and muriate of potash (60 per cent K_2O) respectively. Entire P and K were given as basal dose, as per the treatments. Nitrogen in terms of urea (46 per cent N) was given in two equal splits after the first and second harvests, according to the treatments.

3.2.4.3 Planting

Congosignal is a perennial fodder grass growing to a height of 1.0 - 1.5 m. It is generally propagated through seeds or slips. In the case of vegetative propagation, tillers from the mother clump are used for planting.

In the present experiment, tillers having at least three nodes were selected and slips were prepared by detopping the tillers. Healthy and rooted slips were planted at 40 x 20 cm spacing @ 2 slips $hill^{-1}$ on July 21, 1998.

3.2.4.4 After care

Light intercultivation and hand weeding were done at 15 and 30 days after planting. Hand weedings were also done five days after the first and second fodder harvest. Plant protection measures were carried out as and when necessary.

3.2.4.5 Irrigation

Irrigations as per the treatments were started on January 1, 1999. Plots were given flood irrigation at 4.0 cm depth according to the treatments. Plots receiving the treatments a_1, a_2 ad a_3 were irrigated at 30, 45 and 60 mm CPE intervals respectively and a_4 was the rainfed control. The irrigation as per this schedule continued upto April 17, 1999. The daily rainfall and evaporation data along with the respective dates of irrigation are given in Table 3.2. The total quantity of water received by each irrigation treatment during the entire crop period is shown in Table 3.3.

3.2.4.6 Harvest

Harvesting of the crop was done at a height of 15 cm from the base. Six cuts were taken, starting with the initial cut 60 days after planting. Subsequent harvests were done at 45 days interval.

3.3 Observations recorded

Ten observational plants were selected from each plot after avoiding the border rows. Observations on growth characters were recorded from the observational hills prior to each cut. From this the average of six cuts were worked out.

3.3.1 Biometric observations

3.3.1.1 Plant height

Height of the plant was measured in centimeters from the base of the plant to the tip of the longest leaf in all the observational hills. The mean heights were worked out.

3.3.1.2 Number of tillers hill^{-1}

Number of tillers in the observational plants in each plot were counted and the averages were worked out.

Table 3.2 Rainfall and evaporation during the period of irrigation study (January 1999 - April 1999)

Date	Rainfall (mm)	Evaporation (mm)	Treatment irrigated
January			
1.	-	1.5	a_1, a_2, a_3
2.	2.4	2.9	-
3.	0.8	1.4	-
4.	-	3.0	-
5.	-	2.9	-
6.	-	3.4	-
7.	-	3.2	-
8.	-	2.3	-
9.	-	2.3	-
10.	-	4.0	-
11.	-	3.3	-
12.	-	3.8	-
13.	-	3.5	a_1
14.	-	3.6	-
15.	-	3.3	-
16.	-	3.5	-
17.	-	4.0	-
18.	-	3.5	a_2
19.	-	3.7	-
20.	-	3.6	-
21.	-	3.8	-
22.	-	3.6	a_3. a_1
23.	-	3.0	-

Table 3.2 Contd.....

Date	Rainfall (mm)	Evaporation (mm)	Treatment irrigated
January			
24.	-	3.2	-
25.	-	2.5	-
26.	-	3.6	-
27.	-	4.0	-
28.	-	3.8	-
29.	-	3.7	-
30.	2.0	2.9	-
31.	-	2.2	-
February			
1.	-	4.3	a_1, a_2
2.	-	3.8	-
3.	-	3.9	-
4.	-	3.4	a_3
5.	3.6	3.4	-
6.	62.4	6.2	-
7.	-	3.7	-
8.	11.8	3.3	-
9.	0.8	3.9	-
10.	-	3.6	-
11.	-	3.3	-
12.	-	3.7	-
13.	-	3.9	-
14.	-	4.0	-
15.	-	4.0	-

Table 3.2 Contd.....

Date	Rainfall (mm)	Evaporation (mm)	Treatment irrigated
February			
16.	-	3.9	-
17.	-	3.7	-
18.	-	3.8	a_1
19.	-	3.6	-
20.	-	3.6	-
21.	-	2.6	-
22.	-	3.9	a_2
23.	-	5.2	-
24.	-	4.0	-
25.	-	3.6	-
26.	-	4.0	-
27.	-	4.0	a_3, a_1
28.	-	3.5	-
March			
1.	-	4.3	-
2.	-	4.3	-
3.	-	4.2	-
4.	-	5.2	-
5.	-	4.0	-
6.	-	4.3	-
7.	-	4.0	a_1
8.	-	4.5	-
9.	-	4.0	-

Table 3.2 Contd.....

Date	Rainfall (mm)	Evaporation (mm)	Treatment irrigated
March			
10.	-	4.0	-
11.	-	3.9	-
12.	-	4.0	-
13.	1	4.4	a_1, a_3
14.	-	4.0	-
15.	-	5.7	-
16.	0.8	4.4	-
17.	-	4.8	-
18.	54.2	5.5	-
19.	-	4.7	-
20.	-	4.0	-
21.	-	4.0	-
22.	-	4.0	-
23.	-	4.6	-
24.	-	4.0	-
25.	-	4.0	-
26.	-	3.9	a_1
27.	-	4.0	-
28.	-	4.9	-
29	-	3.9	a_2
30.	2.2	3.5	-
31.	-	4.0	-

Table 3.2 Contd.....

Date	Rainfall (mm)	Evaporation (mm)	Treatment irrigated
April			
1.	-	5.0	-
2.	-	4.6	a_1, a_3
3.	-	3.2	-
4.	-	4.7	-
5.	-	3.7	-
6.	-	4.4	-
7.	10.2	2.2	-
8.	5.0	4.9	-
9.	-	6.0	-
10.	-	3.5	-
11.	-	4.9	-
12.	-	4.3	-
13.	14.0	5.3	-
14.	-	3.9	-
15.	-	4.5	-
16.	-	4.0	-
17.	-	4.8	a_1
18.	0.4	4.0	-
19.	0.6	4.1	a_2
20.	-	3.1	-
21.	-	4.0	-
22.	1.4	3.2	-

Table 3.2 Contd....

Date	Rainfall (mm)	Evaporation (mm)	Treatment irrigated
April			
23.	1.0	2.0	-
24.	78.0	1.5	-
25.	29.2	2.4	-
26.	1.2	2.0	-
27.	-	4.0	-
28.	-	4.1	-
29.	5.6	3.4	-
30.	0.6	4.4	-

Note : a_1 - Irrigation at 30 mm CPE
a_2 - Irrigation at 45 mm CPE
a_3 - Irrigation at 60 mm CPE

Table 3.3 Quantity of water received by each irrigation treatment during the crop period

Treatment	Irrigation (mm)	Effective rainfall (mm)	Total amount of water received (mm)
Irrigation at 30 mm CPE	440	1247.4	1687.4
Irrigation at 45 mm CPE	280	1247.4	1527.4
Irrigation at 60 mm CPE	240	1247.4	1487.4
Rainfed	-	1247.4	1247.4

3.3.1.3 Leaf : stem ratio

The sample plants collected for recording dry matter production at each harvest were separated into leaf and stem, dried, weighed and the leaf : stem ratio was then worked out on dry weight basis. The mean leaf : stem ratio was calculated.

3.3.1.4 Leaf Area Index (LAI)

LAI was worked out using length-width method suggested by Gomez (1972) and averages were worked out.

Leaf area (LA) = Leaf length x leaf breadth x 0.75

$$LAI = \frac{LA}{\text{land area}}$$

3.3.1.5 Green fodder yield

The green matter yield from the net plot area was recorded after each harvest and the total green fodder yield in t ha^{-1} for the entire year was worked out.

3.3.1.6 Dry fodder yield

The ten sample plants collected from each net plot on the day prior to each harvest were sundried and then oven dried to a constant weight at 70^0C. The dry matter yield in t ha^{-1} was computed using the ratio between the fresh weight and oven dry weight of the sample plants at each harvest. From this, the total dry fodder yield obtained during the entire crop period was worked out.

3.3.2 Uptake studies

3.3.2.1 Uptake of N, P, K, Ca and Mg by the plant

Sample plants collected from each plot at each harvest were oven dried and ground to 0.4 mm size in a Willey mill. Composite samples were used for various nutrient analysis. The nitrogen content (Microkjeldhal digestion in H_2SO_4 and distillation method - Jackson, 1973), phosphorus content (Vanedo-molybdate yellow colour method - Jackson, 1973), potassium content (Flame photometer method) and calcium and magnesium contents (Atomic absorption spectrophotometry) in the plant samples were estimated on dry weight basis. N, P, K, Ca and Mg contents were multiplied by total dry matter production ha^{-1} to get the nutrient uptake by the crop.

3.3.3 Physico-chemical properties of soil

3.3.3.1 Physical properties

At the end of the crop period, core samples were collected from undisturbed top soil at 0-15 cm depth and analysed for bulk density, porosity and water holding capacity as described by Gupta and Dakshinamoorthy (1980).

$$\text{Bulk density } (D_b) = \frac{\text{Weight of the soil solid}}{\text{Total volume of the soil}}$$

$$\text{Water holding capacity (per cent)} = \frac{\text{Weight of water in soil}}{\text{Dry weight of soil}} \times 100$$

$$\text{Porosity (per cent)} = \frac{\text{Volume occupied by soil pores}}{\text{Total volume of soil}} \times 100$$

3.3.3.2 Chemical properties

Prior to and after the field experiment soil samples were taken from 0-15 cm depth. The composite samples were then dried in shade and sieved through a 2 mm sieve. The samples collected before and after the experiment were separately analysed for organic carbon content and available nitrogen, phosphorus and potassium contents using the methods mentioned earlier. The nutrient contents were expressed in kg ha^{-1} and organic carbon in percentage.

3.3.4 Quality studies

3.3.4.1 Crude protein content

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

3.3.4.2 Crude fibre content

Crude fibre content was determined by the A.O.A.C method (A.O.A.C., 1975).

3.3.4.3 K : (Ca + Mg) ratio

The K : (Ca + Mg) ratio was worked out from the values of K, Ca and Mg content obtained through the analysis of whole plant samples.

3.3.5 Soil moisture studies

3.3.5.1 Field water use efficiency

Field water use efficiency was calculated by dividing the economic crop yield (Y) by the total amount of water used in the field (WR) and expressed in kg ha^{-1} mm^{-1}.

$$\text{Field water use efficiency (E)} = \frac{Y}{WR}$$

3.3.5.2 Soil moisture depletion pattern

The soil moisture status was found out gravimetrically by taking soil samples from 0 - 30, 30 - 60 and 60 - 90 cm depths one day after the imposition of irrigation and just before the next irrigation in respective treatments. From this data, soil moisture depletion on percentage basis in each irrigation treatment was determined at the end of cropping period.

3.3.6 Root studies

3.3.6.1 Root length

Maximum length of roots of each sample hill was measured and the mean length was recorded in cm.

3.3.6.2 Root weight

Roots were removed from each sample hills, cleaned and dried. The average weights were worked out and expressed in g $hill^{-1}$.

3.3.7 Economics of the study

Net income was worked out after taking into account the cost of cultivation and prevailing market price of fodder grass and expressed as Rs. ha^{-1}.

Net income = Gross income - total expenditure

$$\text{Benefit : cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.4 Yield of coconut

Data on the yield of coconuts (number of nuts $tree^{-1}$) from the palms in the experimental area during the November, January, March and May harvests were recorded for two years prior to the experiment and during the experimental period.

3.5 Statistical analysis

Data relating to different characters were analysed statistically by applying the technique of analysis of variance for factorial experiment in Randomised Block Design (Panse and Sukhatme, 1978). Wherever the F value was found significant, critical differences were worked out at five per cent and one per cent probability level.

RESULTS

4. RESULTS

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala State during the period from July 1998 to June 1999 to study the effect of farm yard manure and chemical fertilizers in relation to irrigation on the yield and quality of congosignal grass grown under partial shade and to assess the changes in physico-chemical properties of the soil due to grass cropping. The results of the experiment are presented here.

4.1 Growth parameters and yield

4.1.1 Plant height (Table 4.1.1.1 and 4.1.1.2)

Rainfed treatment recorded the maximum plant height in first and second harvests. The effect of irrigation on plant height was visible from third harvest onwards. In third harvest, irrigation at 30 mm CPE and 45 mm CPE produced more or less the same results with an average plant height of 96-97 cm. But when irrigation was delayed to 60 mm CPE, a reduction in plant height was observed. Rainfed crop recorded the lowest height of 91.78 cm. In the fourth harvest, irrigation at 30 mm CPE recorded the maximum height of 99.86 cm. A significant reduction in plant height was observed with other irrigation treatments. Rainfed control and least frequent irrigation recorded almost the same result (93.5 cm). Fifth harvest also recorded irrigation at 30 mm CPE as the best treatment giving a plant height of 101.98 cm. Other three treatments showed the same result. At the sixth harvest, however, irrigation at 30 and 45 mm CPE produced more or less the same result. Other treatment levels did not produce any significant change in plant height.

Table 4.1.1.1. Effect of irrigation, FYM and fertilizers on plant height of congosignal

Treatments	Plant height (cm)					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
Irrigation						
a_1	97.38	97.13	96.04	99.86	101.98	111.42
a_2	97.67	96.73	97.01	96.83	98.46	107.86
a_3	99.48	96.28	94.70	93.63	97.73	104.73
a_4	109.55	100.28	91.78	93.44	96.48	101.54
$F_{3,30}$	2.39	2.08	14.82**	36.26**	5.19**	7.22**
SE	3.73	0.79	0.59	0.51	1.04	1.57
CD	—	—	1.71	1.46	2.99	4.55
FYM						
b_1	96.60	95.71	92.97	96.20	98.08	105.70
b_2	105.43	99.50	96.80	95.68	99.24	107.08
$F_{1,30}$	5.59*	9.07**	41.90**	1.02	1.24	0.77
SE	2.64	0.89	0.42	0.36	0.73	1.11
CD	7.62	2.57	1.21	—	—	—
Fertilizer						
c_1	100.40	100.43	97.35	96.34	100.98	109.92
c_2	97.64	94.78	92.41	95.54	96.35	102.85
$F_{1,30}$	3.28	20.05**	69.67**	2.44	19.95**	20.16**
SE	2.64	0.89	0.42	0.36	0.73	1.11
CD	—	2.57	1.21	—	2.12	3.21

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 4.1.1.2. **Interaction effect of irrigation with FYM and fertilizers on plant height of congosignal**

Treatments	Plant height (cm)					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
a_1b_1	90.63	96.58	94.30	98.37	100.97	110.55
a_1b_2	104.12	97.67	97.78	101.35	103.00	112.28
a_2b_1	95.53	92.63	95.40	94.57	97.42	104.20
a_2b_2	99.80	100.83	98.62	99.10	99.50	111.52
a_3b_1	94.50	95.70	90.67	92.67	97.60	105.17
a_3b_2	104.45	96.87	98.73	94.58	97.85	104.30
a_4b_1	105.75	97.92	91.50	99.18	96.35	102.88
a_4b_2	113.35	102.65	92.05	87.69	96.60	100.20
$F_{3,30}$	0.27	1.81	6.95**	53.59**	0.25	1.91
SE	5.28	1.78	0.84	0.71	1.47	2.23
CD	—	—	2.42	2.06	—	—
a_1c_1	101.88	99.30	98.50	98.92	104.47	118.35
a_1c_2	92.87	94.95	93.58	100.80	99.50	104.48
a_2c_1	97.73	103.03	99.97	98.95	101.07	113.13
a_2c_2	97.60	90.43	94.05	94.72	95.85	102.58
a_3c_1	104.15	95.78	93.60	93.23	100.30	102.50
a_3c_2	94.80	96.78	95.80	94.02	95.15	106.97
a_4c_1	113.82	103.60	97.33	94.24	98.07	105.70
a_4c_2	105.28	96.97	86.22	92.63	94.88	97.38
$F_{3,30}$	0.35	4.99**	21.44**	7.25**	0.22	6.49**
SE	5.28	1.78	0.84	0.71	1.47	2.23
CD	—	5.15	2.42	2.06	—	6.43

** Significant at 1 per cent level

The effect of FYM was visible only at first three harvests. In those three harvests, application of FYM @ 7.5 t ha^{-1} resulted in a significant increase in the plant height while the last three harvests did not produce any significant change in plant height with regard to the two levels of FYM.

During first and fourth harvests, 50 per cent reduction in the recommended fertilizer dose did not produce any adverse effect on plant height. But in second, third, fifth and sixth harvests, the recommended levels of fertilizers produced better growth of the plant.

No interaction was observed with irrigation and FYM at first, second, fifth and sixth harvests. But interaction was present in third and fourth harvests. At most frequent (irrigation at 30 mm CPE) and medium (irrigation at 45 mm CPE) levels of irrigation, the trend in plant height with respect to 5.0 and 7.5 t of FYM ha^{-1} was more or less the same. But with the least frequently irrigated (irrigation at 60 mm CPE) crop, FYM given @ 7.5 t ha^{-1} recorded a significant increase in plant height in comparison to FYM @ 5.0 t ha^{-1}. However rainfed crop produced no significant difference under 5.0 and 7.5 t of FYM ha^{-1}. This type of interaction was not visible at fourth harvest, where the rainfed crop with 5.0 t ha^{-1} of FYM was found to be significantly superior to that with 7.5 t ha^{-1} of FYM. The least frequently irrigated crop produced no significant result with FYM @ 5.0 or 7.5 t ha^{-1}. With irrigations at 30 mm and 45 mm CPE, addition of 7.5 t ha^{-1} of FYM was found to be beneficial for plant height.

The interaction of irrigation with chemical fertilizers was observed in second, third and sixth harvests. Most frequent irrigation did not produce any differential result with 100 and 50 per cent package of practices recommendation of fertilizers at second, fourth and sixth harvests. In the third harvest, interaction of irrigation at 30 mm CPE with 100 per cent package of practices recommendation of fertilizers produced significant increase in plant height compared to interaction of irrigation at 30 mm CPE with 50 per cent package of practices recommendation. With medium irrigation, 100 per cent of recommended dose of fertilizers was required for a better plant height. This result was seen in second, third, fourth, fifth and sixth harvests. The least irrigation frequency with 100 or 50 per cent of package of practices recommendation did not produce any differential response in plant height. In second and fourth harvests, rainfed crop did not reveal any significant difference in plant height with 100 and 50 per cent of package of practices recommendation. In the third and sixth harvests, 100 per cent package of practices recommendation with least irrigation gave a better result than with 50 per cent package of practices recommendation.

Interaction of organic manure with fertilizers had no significant effect on plant height.

4.1.2 Tiller number (Table 4.1.2.1 and 4.1.2.2)

A significant difference in tiller number $hill^{-1}$ with various irrigation levels was observed only at fifth and sixth harvests. With most frequent and medium irrigation, no significant difference in average tiller number $hill^{-1}$ was observed. In both the treatments tiller number was in the range of 38 - 39. But, a significant decrease in average tiller number $hill^{-1}$ was observed with least irrigation (35.1 tillers $hill^{-1}$). Rainfed crop produced the minimum tiller number $hill^{-1}$ (29.56).

Table 4.1.2.1. **Effect of irrigation, FYM and fertilizers on tiller number hill^{-1} of congosignal**

Treatments	Tiller number hill^{-1}					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
Irrigation						
a_1	18.95	38.08	38.86	39.48	39.11	38.67
a_2	18.20	36.82	38.57	39.57	38.78	39.88
a_3	18.32	35.68	38.46	38.81	35.18	35.10
a_4	21.41	40.90	38.52	39.04	30.64	29.56
$F_{3,30}$	1.05	1.31	0.06	0.33	36.58**	210.45**
SE	1.46	1.96	0.72	0.63	0.65	0.32
CD	—	—	—	—	1.89	0.92
FYM						
b_1	18.41	35.09	37.55	38.44	36.15	35.58
b_2	20.03	40.65	39.65	40.01	35.71	36.02
$F_{1,30}$	1.21	8.01**	8.40**	6.16*	0.45	1.92
SE	1.03	1.39	0.51	0.45	0.46	0.23
CD	—	4.01	1.48	1.29	—	—
Fertilizer						
c_1	20.51	39.77	39.38	40.21	36.48	37.49
c_2	17.93	35.97	37.82	38.24	35.38	34.11
$F_{1,30}$	3.13	3.76	4.67*	9.71**	2.88	111.89**
SE	1.03	1.39	0.51	0.45	0.46	0.23
CD	—	—	1.48	1.29	—	0.65

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 4.1.2.2. Interaction effect of irrigation with FYM and fertilizers on tiller number hill^{-1} of congosignal

Treatments	Tiller number hill^{-1}					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
a_1b_1	16.70	37.73	36.88	39.35	39.43	37.53
a_1b_2	21.20	38.43	40.83	39.62	38.78	39.80
a_2b_1	18.83	33.37	36.27	37.87	40.52	39.20
a_2b_2	17.57	40.27	40.87	41.27	37.05	40.55
a_3b_1	15.10	34.17	36.82	37.67	34.25	34.13
a_3b_2	21.53	37.20	40.10	39.95	36.12	36.07
a_4b_1	23.03	35.10	40.25	38.88	30.40	31.45
a_4b_2	19.80	46.70	36.80	39.20	30.88	27.67
$F_{3,30}$	2.46	1.47	6.67**	1.49	3.01*	19.83**
SE	2.07	2.87	1.02	0.89	0.92	0.45
CD	—	—	2.95	—	2.67	1.30
a_1c_1	18.83	38.97	39.02	40.30	39.57	40.00
a_1c_2	19.07	37.20	38.70	38.67	38.65	37.33
a_2c_1	20.67	41.50	40.77	40.47	39.80	41.22
a_2c_2	15.73	32.13	36.37	38.67	37.77	38.53
a_3c_1	18.53	37.80	38.82	39.70	36.32	36.82
a_3c_2	18.10	33.57	38.10	37.92	34.05	33.38
a_4c_1	24.03	40.83	38.93	40.37	30.25	31.92
a_4c_2	18.80	40.97	38.12	37.72	31.03	27.20
$F_{3,30}$	0.98	1.10	1.73	0.13	1.14	2.28
SE	2.07	2.87	1.02	0.89	0.92	0.45
CD	—	—	—	—	—	—

** Significant at 1 per cent level

* Significant at 5 per cent level

The effect of FYM was visible in second, third and fourth harvests. FYM given @ 7.5 t ha^{-1} significantly contributed to the increase in tiller number. With 7.5 t ha^{-1} of FYM, tiller number was in the range 39-40 $hill^{-1}$ in the second, third and fourth harvests. FYM @ 5.0 t ha^{-1} produced 35-38 tillers $hill^{-1}$.

Fertilizers given @ 100 and 50 per cent of package of practices recommendations did not produce any significant difference in tiller number at first, second and fifth harvests. But in third, fourth and sixth harvests, plots treated with 100 per cent package of practices recommendation produced more tiller $hill^{-1}$. Maximum number of tillers (40.21 $hill^{-1}$) were produced in the fourth harvest with 100 per cent of recommended fertilizers.

Third, fifth and sixth harvests showed an interaction between irrigation and FYM. In third and sixth harvests, most frequent irrigation with 7.5 t ha^{-1} of FYM produced more tiller number $hill^{-1}$. The same trend was observed for irrigation at 45 and 60 mm CPE in third harvest. In the fifth harvest, irrigation at 45 mm CPE and FYM @ 7.5 t ha^{-1} resulted in less tiller number ha^{-1} in comparison to irrigation at 45 mm CPE and FYM @ 5.0 t ha^{-1}, while, in the sixth harvest, no significant difference was observed with irrigation at 45 mm CPE and FYM given @ 7.5 or 5.0 t ha^{-1}. With least irrigation, FYM @ 5.0 t ha^{-1} and 7.5 t ha^{-1} produced no significant difference in tiller production in the fifth harvest. Plots which received the treatment combination of irrigation at 60 mm CPE and FYM @ 7.5 t ha^{-1} produced a better tiller number than those which received an irrigation of 60 mm CPE and FYM @ 5.0 t ha^{-1}. In the case of rainfed crop, in third and sixth harvests, the crop with 5.0 t ha^{-1} of FYM produced more tillers than with 7.5 t ha^{-1} of FYM; while no significant difference was observed in the fifth harvest.

No interactions were observed with irrigation and fertilizer and fertilizer and organic manure with regard to tiller production.

4.1.3 Leaf : stem ratio (Table 4.1.3.1 and 4.1.3.2)

Difference in leaf : stem ratios at various levels of irrigation were observed in all harvests except the first. In all harvests, rainfed crop recorded the least leaf : stem ratio (0.68 - 1.18), followed by the least irrigated crop (0.83 - 1.63). In the second and fifth harvests, no significant difference in leaf : stem ratio was observed with most and medium frequent irrigation, but in third, fourth and sixth harvests, leaf : stem ratio was high with most frequent irrigation (1.38, 1.86 and 1.96 respectively).

The effect of FYM was observed in first, second and sixth harvests. The lowest level (5.0 t ha^{-1}) of FYM resulted in high leaf : stem ratio in almost all the harvests.

The application of fertilizer lower than the package of practices recommendation resulted in a less leaf : stem ratio (0.78 - 1.60) in comparison to the recommended package of practices in all harvests except the first.

Irrigation and FYM responded independently in the first three harvests but interacted during fourth, fifth and sixth harvests. In fourth harvest, most frequent irrigation recorded more or less the same leaf : stem ratio with FYM @ 7.5 and 5.0 t ha^{-1}. But, medium irrigation along with 7.5 t ha^{-1} of FYM gave a higher leaf : stem ratio than with FYM @ 5.0 t ha^{-1}. The least irrigation and highest dose of FYM resulted in lowest leaf : stem ratio. Rainfed crop recorded high leaf : stem ratio with 5.0 t ha^{-1} FYM than with 7.5 t ha^{-1} of FYM. In the fifth harvest,

Table 4.1.3.1. **Effect of irrigation, FYM and fertilizers on leaf : stem ratio of congosignal**

Treatments	Leaf : stem ratio					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
Irrigation						
a_1	0.81	1.00	1.38	1.86	2.00	1.96
a_2	0.81	1.04	1.09	1.69	1.99	1.88
a_3	0.83	0.89	0.97	1.63	1.53	1.49
a_4	0.68	0.74	0.86	1.03	1.18	1.15
$F_{3,30}$	2.76	19.48**	24.12**	134.52**	316.25**	498.16**
SE	0.04	0.03	0.04	0.03	0.02	0.02
CD	—	0.09	0.13	0.09	0.06	0.05
FYMs						
b_1	0.83	0.88	1.09	1.57	1.66	1.65
b_2	0.73	0.95	1.06	1.54	1.69	1.59
$F_{1,30}$	5.69*	5.18*	0.63	0.61	1.32	15.26**
SE	0.03	0.02	0.03	0.02	0.02	0.01
CD	0.09	0.06	—	—	—	0.03
Fertilizer						
c_1	0.79	0.95	1.19	1.69	1.75	1.70
c_2	0.78	0.88	0.96	1.42	1.60	1.55
$F_{1,30}$	0.07	5.31*	24.99**	72.90**	43.96**	75.76**
SE	0.03	0.02	0.03	0.02	0.02	0.01
CD	—	0.06	0.09	0.06	0.05	0.03

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 4.1.3.2. **Interaction effect of irrigation with FYM and fertilizers on leaf : stem ratio of congosignal**

Treatments	Leaf : stem ratio					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
a_1b_1	0.85	0.92	1.39	1.84	1.94	1.95
a_1b_2	0.77	1.07	1.36	1.89	2.06	1.98
a_2b_1	0.91	0.97	1.13	1.60	1.99	1.93
a_2b_2	0.70	1.10	1.05	1.77	1.99	1.84
a_3b_1	0.82	0.89	0.94	1.71	1.60	1.54
a_3b_2	0.85	0.88	1.01	1.56	1.46	1.44
a_4b_1	0.74	0.73	0.92	1.11	1.13	1.20
a_4b_2	0.61	0.75	0.81	0.95	1.24	1.10
$F_{3,30}$	1.38	1.50	0.78	6.15^{**}	7.38^{**}	3.48^{*}
SE	0.06	0.04	0.06	0.04	0.03	0.02
CD	—	—	—	0.13	0.09	0.07
a_1c_1	0.83	1.05	1.61	1.94	2.02	2.02
a_1c_2	0.80	0.95	1.41	1.80	1.98	1.91
a_2c_1	0.80	1.07	1.41	1.86	2.06	1.96
a_2c_2	0.82	1.01	1.04	1.51	1.92	1.81
a_3c_1	0.91	0.92	1.05	1.86	1.68	1.58
a_3c_2	0.76	0.85	0.90	1.41	1.38	1.40
a_4c_1	0.62	0.76	0.96	1.09	1.24	1.22
a_4c_2	0.73	0.71	0.77	0.96	1.13	1.08
$F_{3,30}$	1.63	0.13	3.48^{*}	6.51^{**}	6.18^{**}	0.68
SE	0.06	0.04	0.06	0.04	0.03	0.02
CD	—	—	0.18	0.13	0.09	—

** Significant at 1 per cent level * Significant at 5 per cent level

irrigation at 30 mm CPE and FYM @ 7.5 t ha^{-1} gave higher leaf : stem ratio than the crop which received irrigation at 30 mm CPE and FYM @ 5.0 t ha^{-1}. No significant difference was observed between the combinations of irrigation at 45 mm CPE and FYM @ 5.0 t ha^{-1} or 7.5 t ha^{-1}. Irrigation at 60 mm CPE and 5.0 t ha^{-1} of FYM recorded an increase in leaf : stem ratio in comparison to irrigation at 60 mm CPE and FYM @ 7.5 t ha^{-1}. Rainfed crop with 7.5 t ha^{-1} of FYM gave a higher leaf : stem ratio than with 5.0 t ha^{-1} of FYM. In the sixth harvest, both levels of FYM resulted in more or less the same leaf : stem ratio with most frequent irrigation. With medium (irrigation at 45 mm CPE) and least frequent irrigation (irrigation at 60 mm CPE) and also with the rainfed crop, highest dose of FYM resulted in lowest leaf : stem ratio.

Significant interactions between irrigation and chemical fertilizers were observed in third, fourth and fifth harvests with regard to the leaf : stem ratio. In third harvest, 50 per cent reduction in recommended package of practices resulted in a reduction in leaf : stem ratio at 30 and 45 mm CPE irrigation levels and also under rainfed condition. While, at the lowest level of irrigation (irrigation 60 mm CPE) there was no significant difference in leaf : stem ratio of the plant; whatever be the level of fertilizers. In the fourth harvest, a significant reduction in leaf : stem ratio was observed when the fertilizer dose was reduced to 50 per cent of the package of practices recommendation in all irrigation and rainfed treatments. In fifth harvest, 50 per cent reduction in package of practices recommendation did not produce any significant change in leaf : stem ratio at 30 mm CPE irrigation level; but, a reduction in leaf : stem ratio was observed at 45 and 60 mm CPE irrigation levels and under rainfed condition.

4.1.4 Leaf Area Index (Table 4.1.4.1 and 4.1.4.2)

A difference in LAI with various levels of irrigation was observed in all harvests except the first. In second harvest, most frequently irrigated crop and rainfed crop recorded higher LAI (7.24 and 7.65 respectively). But, with irrigations at 45 and 60 mm CPE there were significant reductions in LAI which were on par (5.59 and 6.22 respectively). In third harvest, LAI was not significantly affected with irrigation at 30 or 45 mm CPE, but, it was decreased with irrigation at 60 mm CPE and the rainfed treatment. In fourth harvest, maximum LAI (7.14) was recorded with irrigation at 30 mm CPE and least LAI (4.68) with the rainfed control. A significant reduction in LAI was seen when irrigation was delayed. Fifth harvest did not produce any significant difference in LAI with irrigations at 30 or 45 mm CPE, but, reduction in LAI was observed in treatments with irrigation at 60 mm CPE and also under rainfed condition. Sixth harvest recorded a significant reduction in LAI with increase in irrigation interval. Maximum LAI (7.32) was recorded with irrigation at 30 mm CPE and minimum LAI (5.85) with rainfed condition.

FYM @ 7.5 t ha^{-1} was found to increase the LAI significantly in first, second and fifth harvests. In other three harvests, both levels of FYM gave almost the same Leaf Area Indices.

Fifty per cent package of practices recommendation resulted in reduced LAI in all the harvests. Leaf Area Indices were in the range 6.16 - 7.22 with 100 per cent of recommended fertilizers and 5.50 - 6.79 with 50 per cent of the fertilizers.

Table 4.1.4.1. Effect of irrigation, FYM and fertilizers on Leaf Area Index of congosignal

Treatments	Leaf Area Index					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
Irrigation						
a_1	6.23	7.24	6.64	7.14	7.21	7.32
a_2	5.78	5.59	6.78	6.68	7.06	6.98
a_3	5.93	6.22	6.16	4.90	6.83	6.49
a_4	7.50	7.65	5.68	4.68	6.46	5.85
$F_{3,30}$	2.28	10.15**	10.77**	307.92**	24.49**	274.13**
SE	0.519	0.29	0.15	0.07	0.07	0.04
CD	—	0.85	0.44	0.20	0.19	0.11
FYMs						
b_1	5.62	6.22	6.34	5.87	6.80	6.70
b_2	7.10	7.13	6.28	5.83	6.98	6.62
$F_{1,30}$	8.13**	9.58**	0.15	0.30	7.98**	3.85
SE	0.37	0.21	0.11	0.05	0.05	0.03
CD	1.06	0.60	—	—	0.13	—
Fertilizers						
c_1	7.22	7.06	6.89	6.16	7.00	6.79
c_2	5.50	6.28	5.74	5.54	6.79	6.53
$F_{1,30}$	11.05**	7.00*	57.58**	78.47**	9.95**	46.02**
SE	0.37	0.21	0.11	0.05	0.05	0.03
CD	1.06	0.60	0.31	0.14	0.13	0.08

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 4.1.4.2. **Interaction effect of irrigation with FYM and fertilizers on Leaf Area Index of congosignal**

Treatments	Leaf Area Index					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
a_1b_1	4.13	6.08	6.93	6.88	6.57	7.19
a_1b_2	8.33	8.40	6.34	7.40	7.84	7.45
a_2b_1	6.38	5.54	6.25	6.83	7.16	7.05
a_2b_2	5.17	5.64	7.30	6.52	6.96	6.91
a_3b_1	4.95	5.69	6.31	5.00	6.86	6.57
a_3b_2	6.91	6.75	6.01	4.80	6.81	6.41
a_4b_1	7.01	7.57	5.88	4.76	6.59	5.98
a_4b_2	7.98	7.73	5.49	4.60	6.33	5.72
$F_{3,30}$	4.67**	3.10*	6.16**	7.09**	30.41**	8.89**
SE	0.73	0.42	0.21	0.10	0.09	0.05
CD	2.12	1.20	0.62	0.29	0.27	0.16
a_1c_1	6.50	7.41	7.45	7.58	7.37	7.44
a_1c_2	5.97	7.06	5.82	6.69	7.04	7.20
a_2c_1	6.32	5.41	7.23	7.09	7.12	7.06
a_2c_2	5.23	5.78	6.32	6.27	7.00	6.91
a_3c_1	6.94	6.71	6.75	5.08	6.82	6.60
a_3c_2	4.92	5.73	5.56	4.73	6.85	6.38
a_4c_1	9.13	8.72	6.12	4.90	6.67	6.07
a_4c_2	5.87	6.57	5.25	4.45	6.25	5.63
$F_{3,30}$	1.33	3.29*	1.34	3.60*	2.44	2.55
SE	0.73	0.42	0.21	0.10	0.09	0.05
CD	—	1.20	—	0.29	—	—

** Significant at 1 per cent level

* Significant at 5 per cent level

Significant interaction between irrigation and FYM was observed at all harvests with reference to LAI. At all harvests, except third, an increase in FYM along with irrigation at 30 mm CPE resulted in high LAI. With medium irrigation frequency, no significant difference was observed with the two levels of FYM at first, second, fifth and sixth harvests. While in third harvest, LAI was high with irrigation at 45 mm CPE and FYM @ 7.5 t ha^{-1}. When irrigation was delayed (i.e., irrigation at 60 mm CPE); the levels of FYM produced no significant difference in LAI at all harvests. Rainfed crop also responded similarly as the least frequently irrigated crop.

Irrigation and fertilizers were found to interact in second and fourth harvests. Second harvest produced no significant difference in LAI with 100 or 50 per cent of package of practices recommendation at all irrigation levels. However, in rainfed crop, 50 per cent reduction in package of practices recommendation resulted in a significant reduction in LAI. In the fourth harvest, irrespective of the frequency of irrigation or rainfed nature, the crop showed a reduction in LAI with 50 per cent reduction in package of practices recommendation.

4.1.5 Green fodder yield (Table 4.1.5.1 and 4.1.5.2)

Significant difference in green fodder yield with irrigation was observed from third to sixth harvests. In the first two harvests, rainfed treatment produced equally good or higher green fodder yields than the irrigated treatments. In third harvest, no significant difference was observed at irrigation levels 30 and 45 mm CPE with regard to green fodder yield (12 t ha^{-1}). Delayed irrigation resulted in yield reduction. Rainfed crop recorded the least yield (9.51 t ha^{-1}).

Table 4.1.5.1. **Effect of irrigation, FYM and fertilizers on green fodder yield of congosignal**

Treatments	Green fodder yield (t ha^{-1})					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
Irrigation						
a_1	15.73	14.89	12.77	12.12	15.27	15.68
a_2	16.39	15.85	12.60	10.12	14.83	15.63
a_3	17.21	15.35	10.02	9.80	12.53	11.52
a_4	18.75	15.66	9.51	8.94	10.06	10.33
$F_{3,30}$	0.89	0.58	98.86**	114.15**	203.75**	277.07**
SE	1.38	3.46	0.17	0.13	0.17	0.17
CD	—	—	0.49	0.36	0.48	0.48
FYM						
b_1	16.28	14.97	11.14	10.26	13.15	13.41
b_2	17.77	15.91	11.31	10.22	13.20	13.16
$F_{1,30}$	1.17	2.94	1.06	0.11	0.07	2.28
SE	0.98	0.39	0.12	0.09	0.12	0.12
CD	—	—	—	—	—	—
Fertilizers						
c_1	17.42	17.11	11.67	10.69	13.83	14.01
c_2	16.62	13.77	10.78	9.80	12.52	12.57
$F_{1,30}$	0.33	36.84**	26.77**	49.63**	60.40**	74.06**
SE	0.98	0.39	0.12	0.09	0.12	0.12
CD	—	1.12	0.35	0.26	0.34	0.34

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 4.1.5.2. **Interaction effect of irrigation with FYM and fertilizers on green fodder yield of congosignal**

Treatments	Green fodder yield (t ha^{-1})					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
a_1b_1	14.42	14.51	12.09	12.13	14.75	15.50
a_1b_2	17.05	15.27	13.45	12.12	15.80	15.85
a_2b_1	15.81	14.51	12.62	10.16	14.66	15.60
a_2b_2	16.97	17.20	12.59	10.08	15.01	15.67
a_3b_1	17.36	15.74	10.30	9.77	12.85	12.19
a_3b_2	17.05	14.97	9.74	9.83	12.20	10.84
a_4b_1	17.52	18.12	9.54	9.00	10.35	10.37
a_4b_2	20.00	16.20	9.48	8.87	9.78	10.29
$F_{3,30}$	0.25	1.67	5.80**	0.11	5.82**	5.11**
SE	1.95	0.78	0.24	0.18	0.24	0.24
CD	—	—	0.70	—	0.69	0.68
a_1c_1	14.73	16.66	13.42	13.10	16.51	16.99
a_1c_2	16.74	13.12	12.12	11.15	14.03	14.36
a_2c_1	16.35	17.66	12.92	10.29	15.31	16.46
a_2c_2	16.43	14.04	12.29	9.94	14.35	14.80
a_3c_1	17.82	17.13	10.41	10.05	13.15	11.99
a_3c_2	16.59	13.58	9.63	9.54	11.90	11.04
a_4c_1	20.77	16.98	9.92	9.31	10.33	10.58
a_4c_2	16.74	14.35	9.10	8.57	9.80	10.09
$F_{3,30}$	0.85	0.19	0.74	8.31**	6.25**	7.84**
SE	1.95	0.78	0.24	0.18	0.24	0.24
CD	—	—	—	0.52	0.69	0.68

** Significant at 1 per cent level   * Significant at 5 per cent level

FYM, when applied at 7.5 t ha^{-1} did not improve the green fodder yield. This trend was seen at all harvests.

A reduction in package of practices recommendation of fertilizers by 50 per cent resulted in a significant reduction in green fodder yield at all harvests except the first harvest. The green fodder yields were 10 - 17 t ha^{-1} with full dose of fertilizers and 9.0 - 13 t ha^{-1} with 50 per cent of recommended fertilizers.

An interaction of irrigation with manures was seen at third, fifth and sixth harvests. Most frequent irrigation, along with 7.5 t ha^{-1} of FYM recorded high green fodder yield in third and sixth harvests, while in fifth harvest even 5.0 t ha^{-1} of FYM produced a good yield. Also, higher dose of FYM did not produce any significant positive effect on green fodder yield with delayed irrigation and the rainfed treatment.

Significant interaction was also observed with irrigation and fertilizers in fourth, fifth and sixth harvests. At all these harvests, most frequent and medium irrigations along with full dose of recommended fertilizers produced higher green fodder yield. In fourth harvest, a 50 per cent reduction in recommended dose of fertilizers did not show any significant difference in comparison with the full dose of fertilizers at 60 mm CPE irrigation. In the fifth and sixth harvests, 100 per cent fertilizer applied plots performed well than plots received 50 per cent of recommended fertilizers at 60 mm CPE irrigation. In rainfed crop, at fifth and sixth harvests, full or half the dose of recommended fertilizers did not produce any significant difference in green fodder yield.

4.1.6 Dry fodder yield (Table 4.1.6.1 and 4.1.6.2)

Plots with less frequent irrigation (irrigation at 60 mm CPE) recorded a higher dry fodder yield in first harvest (6.14 t ha^{-1}), while, no significant difference was seen with various levels of irrigation or rainfed condition during the second harvest. In third harvest, irrigation at 30 or 45 mm CPE did not produce any significant difference in dry fodder yield, but, irrigation at 60 mm CPE resulted in a significant decrease in dry fodder yield which was on par with the yields from rainfed plots. Fourth harvest also showed the same trend; while in the fifth harvest, no significant difference in dry fodder yield was observed at the three levels of irrigation. Again in the sixth harvest, between most frequent and medium irrigation, no significant difference was seen with respect to dry matter yield (4.62 and 4.61 t ha^{-1} respectively). A significant yield reduction was observed in most delayed irrigation (3.19 t ha^{-1}). Rainfed crop recorded the lowest dry fodder yield at all harvests (2.63 - 5.68 t ha^{-1}).

An increase in FYM did not produce any increase in dry fodder yield at all harvests.

A reduction in dry fodder yield was seen at all harvest stages except first, with 50 per cent reduction in recommended dose of fertilizers.

In third and sixth harvests, an interaction between irrigation and organic manure was seen. With most frequent irrigation, third harvest gave a higher dry fodder yield at 7.5 t ha^{-1} of FYM, while no significant difference in dry fodder yield was seen at the two levels of FYM in sixth harvest. With medium and least frequent irrigation, no significant difference in dry matter yield was seen with 5.0 and 7.5 t ha^{-1} of FYM in third harvest, while in sixth harvest, 5.0 t ha^{-1} of FYM

Table 4.1.6.1. **Effect of irrigation, FYM and fertilizers on dry fodder yield of congosignal**

Treatments	Dry fodder yield (t ha^{-1})					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
Irrigation						
a_1	4.41	4.66	3.66	3.59	4.65	4.62
a_2	4.29	4.71	3.61	3.00	4.44	4.61
a_3	6.14	4.39	2.87	2.88	4.29	3.19
a_4	5.68	4.24	2.74	2.63	3.03	2.94
$F_{3,30}$	3.03*	1.75	93.87**	111.09**	9.26**	148.22**
SE	0.53	0.17	0.05	0.04	0.24	0.07
CD	1.53	—	0.14	0.11	0.70	0.21
FYM						
b_1	5.11	4.40	3.19	3.03	4.23	3.90
b_2	5.15	4.60	3.25	3.01	3.97	3.78
$F_{1,30}$	0.00	1.41	1.46	0.27	1.17	2.98
SE	0.37	0.12	0.04	0.03	0.17	0.05
CD	—	—	—	—	—	—
Fertilizer						
c_1	5.13	5.06	3.35	3.16	4.39	4.09
c_2	5.12	3.94	3.09	2.89	3.81	3.59
$F_{1,30}$	0.00	43.94**	26.46**	49.64**	5.86*	46.92**
SE	0.37	0.12	0.04	0.03	0.17	0.05
CD	—	0.34	0.10	0.08	0.49	0.15

** Significant at 1 per cent level * Significant at 5 per cent level

Table 4.1.6.2. Interaction effect of irrigation with FYM and fertilizers on dry fodder yield of congosignal

Treatments	Dry fodder yield (t ha^{-1})					
	Harvest I	Harvest II	Harvest III	Harvest IV	Harvest V	Harvest VI
a_1b_1	4.61	4.66	3.46	3.58	4.59	4.50
a_1b_2	4.21	4.66	3.85	3.60	4.72	4.75
a_2b_1	4.04	4.35	3.62	3.01	4.39	4.78
a_2b_2	4.54	5.07	3.61	2.99	4.50	4.43
a_3b_1	6.40	4.49	2.95	2.89	4.86	3.41
a_3b_2	5.88	4.30	2.79	2.87	3.73	2.98
a_4b_1	5.40	4.10	2.73	2.65	3.10	2.94
a_4b_2	5.96	4.37	2.75	2.60	2.95	2.95
$F_{3,30}$	0.30	1.35	5.62**	0.13	1.51	4.64**
SE	0.53	0.24	0.07	0.05	0.34	0.10
CD	1.53	—	0.20	—	—	0.30
a_1c_1	4.24	5.37	3.85	3.89	4.93	5.12
a_1c_2	4.57	3.95	3.47	3.29	4.39	4.13
a_2c_1	4.32	5.23	3.70	3.05	4.59	4.91
a_2c_2	4.26	4.19	3.52	2.95	4.30	4.30
a_3c_1	6.26	4.96	2.98	2.97	4.94	3.39
a_3c_2	6.01	3.83	2.76	2.79	3.64	3.00
a_4c_1	5.72	4.68	2.86	2.73	3.12	2.96
a_4c_2	5.64	3.80	2.62	2.52	2.94	2.93
$F_{3,30}$	0.05	0.44	0.73	8.14**	1.10	7.51**
SE	0.75	0.24	0.07	0.05	0.34	0.10
CD	—	—	—	0.16	—	0.30

** Significant at 1 per cent level * Significant at 5 per cent level

recorded better yield than 7.5 t ha^{-1} of FYM. In rainfed crop, no significant difference was seen in dry fodder yield with respect to two levels of FYM.

Interaction was also observed in fourth and sixth harvests between irrigation and fertilizers. Most frequent irrigation with recommended fertilizers recorded better dry fodder yields in fourth and sixth harvests. No significant difference in dry fodder yield was seen with both levels of fertilizer and irrigation at 45 mm CPE in fourth harvest, but, with most delayed irrigation and rainfed crop, the recommended dose of fertilizers recorded better dry fodder yields. In sixth harvest, medium frequent (irrigation at 45 mm CPE) and delayed irrigation (irrigation at 60 mm CPE) along with recommended full dose of fertilizers were found to be better than 50 per cent of fertilizers with regard to dry fodder yield. In rainfed crop, no significant difference in dry fodder yield was observed with the two levels of FYM.

4.2 Uptake studies

4.2.1 Uptake of nitrogen (Table 4.2.1.1 and 4.2.1.2)

Irrigation was found to be significantly affecting the nitrogen uptake by congosignal. Maximum uptake of 366.1 kg N ha^{-1} was observed in most frequently irrigated treatment which was on par with the treatment receiving medium level of irrigation. The rainfed crop recorded least uptake of nitrogen (278.0 kg ha^{-1}) which was significantly lower than any irrigation treatment.

Farm yard manure application also significantly influenced the uptake of nitrogen, but, the two levels of FYM did not show any significant difference between them in increasing nitrogen uptake.

Table 4.2.1.1. **Effect of irrigation, FYM and fertilizers on the uptake of nitrogen, phosphorus, potassium, calcium and magnesium by congosignal**

Treatments	Uptake of nutrients (kg ha^{-1})				
	N	P	K	Ca	Mg
Irrigation					
a_1	36.61	5.87	29.38	12.58	16.11
a_2	34.52	4.99	28.02	11.55	15.74
a_3	31.67	3.57	24.38	11.38	14.44
a_4	27.80	3.17	21.21	10.25	13.65
$F_{3,30}$	18.07**	30.11**	13.89**	6.14**	3.24*
SE	0.90	0.23	0.99	0.39	0.64
CD	2.59	0.66	2.86	1.12	1.83
FYM					
b_1	32.94	4.60	26.00	11.39	15.32
b_2	32.36	4.20	25.49	11.49	14.66
$F_{1,30}$	0.42**	3.11	0.26	0.07	1.08
SE	0.64	0.16	0.70	0.27	0.45
CD	1.83	—	—	—	—
Fertilizer					
c_1	34.50	4.76	28.45	12.06	16.06
c_2	30.80	4.04	23.05	10.82	13.91
$F_{1,30}$	16.98**	9.79**	29.75**	10.15**	11.43**
SE	0.64	0.16	0.70	0.27	0.45
CD	1.83	0.47	2.02	0.79	1.30

** Significant at 1 per cent level * Significant at 5 per cent level

Table 4.2.1.2. **Interaction effect of irrigation, FYM and fertilizers on the uptake of nitrogen, phosphorus, potassium, calcium and magnesium**

Treatments	Uptake of nutrients (kg ha^{-1})				
	N	P	K	Ca	Mg
a_1b_1	36.01	5.92	29.28	12.25	16.27
a_1b_2	37.21	5.82	29.49	12.92	15.95
a_2b_1	34.77	5.67	28.37	11.48	15.93
a_2b_2	33.28	4.31	27.69	11.63	15.56
a_3b_1	30.05	3.72	25.30	11.68	15.53
a_3b_2	27.70	3.42	23.46	11.08	13.34
a_4b_1	27.89	3.09	21.06	10.16	13.53
a_4b_2	1.12**	3.25	21.36	10.33	13.78
$F_{3,30}$	1.27	2.14	0.25	0.46	0.69
SE	3.67	0.32	1.40	0.55	0.90
CD	—	—	—	—	—
a_1c_1	39.70	6.35	32.48	13.42	17.07
a_1c_2	33.46	5.39	26.29	11.75	15.15
a_2c_1	36.18	5.22	30.87	12.14	16.76
a_2c_2	32.87	4.77	25.18	10.96	14.73
a_3c_1	32.58	3.96	26.93	11.91	16.28
a_3c_2	30.76	3.18	21.83	10.84	12.60
a_4c_1	29.48	3.51	23.52	10.75	14.13
a_4c_2	26.11	2.83	18.89	9.74	13.17
$F_{3,30}$	1.09**	0.1	0.12	0.15	0.79
SE	1.27	0.32	1.40	0.55	0.90
CD	3.67	—	—	—	—

There was significant increase in the uptake of nitrogen with the application of chemical fertilizers. Fertilizer dose equal to the recommended package was highly effective in increasing nitrogen uptake than a 50 per cent reduction in the fertilizer dose. Nitrogen uptakes were 345 kg ha^{-1} with full dose of recommended fertilizers and 308 kg ha^{-1} with 50 per cent of fertilizers.

Significant interactions were noticed between irrigation + FYM application and irrigation + chemical fertilizer application in the first harvest. Uptake of nitrogen was highest when higher dose (7.5 t ha^{-1}) of FYM was applied with irrigation at 30 mm CPE. However, it had no visible distinction from the treatment combinations viz., irrigation at 30 mm CPE + lower level (5.0 t ha^{-1}) of FYM and irrigation at 45 mm CPE + lower or higher level of FYM. The nitrogen uptake was least in the rainfed crop which received lower level of FYM. But the uptake value (277 kg ha^{-1}) did not differ significantly from those treatments receiving least frequent irrigation with either high or low level of FYM and rainfed crop with higher level of FYM.

Highest interaction effect between irrigation and chemical fertilizer was observed with highest level of irrigation and 100 per cent of chemical fertilizer. This was on par with the treatments receiving highest irrigation + low level of fertilizer and medium level of irrigation + high level of fertilizer. Lowest nitrogen uptake (261.1 kg ha^{-1}) was noticed in rainfed crop when the level of fertilizer was 50 per cent less than the recommended dose. There was no remarkable difference between this treatment and the treatment involving least frequent irrigation + 50 per cent of the recommended fertilizers.

4.2.2 **Uptake of phosphorus** (Table 4.2.1.1 and 4.2.1.2)

Irrigation and chemical fertilizers had significant effect on the uptake of phosphorus by the crop. Phosphorus uptake was highest with most frequently irrigated crop (58.7 kg ha^{-1}) which differed considerably from other levels of irrigation and rainfed condition. Rainfed plots showed the least uptake of phosphorus (317 kg ha^{-1}) which was on par with the uptake of P in least irrigated plots.

Hundred per cent of package of practices recommendation of fertilizers was found to be best in increasing phosphorus uptake. Fifty per cent reduction in chemical fertilizers markedly decreased the phosphorus uptake. P uptakes were 47.6 kg ha^{-1} with full dose of fertilizers and 40.4 kg ha^{-1} with 50 per cent of fertilizers.

Independent effect of organic manure and interaction effects of irrigation + organic manure, irrigation + chemical fertilizers and organic manures + fertilizers were non-significant on the uptake of P by congosignal.

4.2.3 **Uptake of potassium** (Table 4.2.1.1 and 4.2.1.2)

Potassium uptake showed almost the same trend as phosphorus uptake. Irrigation significantly affected the potassium uptake, which was maximum with highest irrigation treatment (293.8 kg ha^{-1}). The uptake was on par with that at medium level of irrigation. Lowest uptake was recorded in the rainfed treatment (102.5 kg ha^{-1}).

Remarkably higher uptake of potassium was observed with the application of higher dose of chemical fertilizers. The uptake values of potassium were 284.5 kg ha^{-1} with 100 per cent of recomended fertilizers and 230.5 kg ha^{-1} with 50 per cent of recommended fertilizers.

Table 4.3.1.1. **Effect of irrigation, FYM and fertilizers on bulk density, water holding capacity and porosity of soil**

Treatments	Bulk density ($g\ cc^{-1}$)	Water holding capacity (per cent)	Porosity (per cent)
Irrigation			
a_1	1.33	27.05	38.42
a_2	1.33	27.09	38.52
a_3	1.34	24.89	35.85
a_4	1.35	23.96	34.64
$F_{3,30}$	16.41**	26.36**	56.02**
SE	0.00	0.31	0.26
CD	0.01	0.89	0.74
FYM			
b_1	1.34	25.35	36.51
b_2	1.33	26.14	37.20
$F_{1,30}$	0.67	6.55*	7.32**
SE	0.00	0.22	0.18
CD	—	0.63	0.53
Fertilizer			
c_1	1.33	26.54	37.75
c_2	1.34	24.96	35.96
$F_{1,30}$	16.33**	26.61**	48.32**
SE	0.00	0.22	0.18
CD	0.00	0.63	0.53

** Significant at 1 per cent level * Significant at 5 per cent level

Table 4.3.1.2. **Interaction effect of irrigation, FYM and fertilizers on bulk density, water holding capacity and porosity of soil**

Treatments	Bulk density (g cc^{-1})	Water holding capacity (per cent)	Porosity (per cent)
a_1b_1	1.34	25.68	37.03
a_1b_2	1.32	28.42	39.81
a_2b_1	1.33	26.05	37.43
a_2b_2	1.32	28.13	39.61
a_3b_1	1.33	26.08	37.07
a_3b_2	1.35	23.69	34.63
a_4b_1	1.35	23.60	34.51
a_4b_2	1.35	24.32	34.77
$F_{3,30}$	11.30**	13.79**	20.84**
SE	0.00	0.43	0.36
CD	0.01	1.25	1.05
a_1c_1	1.32	27.93	39.31
a_1c_2	1.34	26.18	37.53
a_2c_1	1.32	27.56	39.14
a_2c_2	1.33	26.62	37.91
a_3c_1	1.34	25.83	37.03
a_3c_2	1.34	23.94	34.68
a_4c_1	1.34	24.83	35.54
a_4c_2	1.35	23.08	33.74
$F_{3,30}$	0.81	0.50	0.78
SE	0.00	0.43	0.36
CD	—	—	—

** Significant at 1 per cent level

the next best result (1.33 g cc^{-1}). Highest irrigation frequency with 5.0 t ha^{-1} of FYM gave a significant increase in bulk density (1.33 g cc^{-1}) over irrigation at 30 mm CPE and 7.5 t ha^{-1} of FYM. Bulk density of soil under rainfed condition with two levels of FYM and least frequent irrigation with higher dose of FYM were the highest (1.35 g cc^{-1}).

Interaction effects of irrigation with fertilizer and fertilizer with FYM were not significant on the bulk density of soil.

4.3.1.2 Water holding capacity (Table 4.3.1.1 and 4.3.1.2)

Effect of irrigation was significant on the water holding capacity of soil. The highest water holding capacity of 27.09 per cent was recorded for irrigation at 45 mm CPE which was on par with the water holding capacity in most frequently irrigated treatment. Least frequent irrigation and rainfed condition showed remarkable reductions in water holding capacities. Water holding capacity was lowest for rainfed treatment (23.96 per cent).

Organic manure application had slight influence on water holding capacity. Higher dose of FYM increased the water holding capacity compared to lower levels. Water holding capacities were 26.14 per cent with higher dose of FYM and 25.35 per cent with lower dose of FYM.

Fertilizer application was found to favour the water holding capacity significantly. Full dose of recommended fertilizers resulted in higher water holding capacity (26.54 per cent) compared to 50 per cent of package of practices recommendation (24.96 per cent).

Irrigation and FYM had significant interaction effect on water holding capacity of soil. Most frequent irrigation with 7.5 t ha^{-1} of FYM had the highest water holding capacity of 28.42 per cent which was on par with 7.5 t ha^{-1} of FYM and medium level of irrigation. Rainfed treatment with low level of FYM recorded the lowest water holding capacity (23.60 per cent) which was on par with lowest level of irrigation and 5.0 t ha^{-1} of FYM and rainfed with 7.5 t ha^{-1} of FYM.

The interaction between FYM and fertilizers did not affect the water holding capacity of soil significantly.

4.3.1.3 Porosity (Table 4.3.1.1 and 4.3.1.2)

Significant changes in soil porosity were observed with irrigation. The trend in soil porosity was similar to that of water holding capacity. Porosity was highest in treatment with irrigation at 45 mm CPE (38.52 per cent) which was on par with highest irrigation treatment. Lowest soil porosity was recorded in rainfed treatment (34.64 per cent).

Highest FYM treatment showed a slight improvement in soil porosity. Soil porosity was 37.20 per cent with the application of 7.5 t ha^{-1} FYM. With 5.0 t ha^{-1} of FYM, soil porosity was 36.51 per cent.

Application of 100 per cent of recommended fertilizers was better than the lower fertilizer treatment with respect to soil porosity. Soil porosity values were 37.75 per cent and 35.96 per cent respectively for treatments with full and 50 per cent of the chemical fertilizers.

Interaction of irrigation with FYM had significant influence on soil porosity. Irrigation at 30 mm CPE and 7.5 t ha^{-1} of FYM gave the highest soil porosity (39.81 per cent) which was on par with irrigation at 45 mm CPE and 7.5 t ha^{-1} of FYM. Rainfed treatment with 5.0 t ha^{-1} of FYM showed the least soil porosity (34.51 per cent) which was on par with the lowest irrigation treatment along with 5.0 t ha^{-1} FYM and rainfed control with 7.5 t ha^{1} FYM. The combination of irrigation levels (irrigation at 30, 45 or 60 mm CPE) and 5.0 t ha^{-1} of FYM did not bring about any significant change in soil porosity.

Interaction effect of FYM and fertilizer was found to be non significant with respect to soil porosity.

4.3.2 Chemical properties of soil

4.3.2.1 Organic carbon (Table 4.3.2.1 and 4.3.2.2)

Organic carbon content of the soil showed significant difference among various irrigation treatments. Highest level of irrigation showed the highest organic carbon (0.61 per cent) content in soil. Organic carbon content of rainfed treatment was the lowest (0.47 per cent).

Application of 7.5 t ha^{-1} of FYM significantly increased the soil organic carbon content over 5.0 t ha^{-1} of FYM. Organis carbon contents of the soil were 0.59 and 0.52 per cent respectively with the applications of 7.5 and 5.0 t of FYM ha^{-1}.

Not much influence was imparted by fertilizer application, irrigation + FYM interaction or irrigation + fertilizer interaction on soil organic carbon content.

4.3.2.2 Available nitrogen (Table 4.3.2.1 and 4.3.2.2)

None of the irrigation, FYM or fertilizer treatments either independently or in combination affected the available nitrogen status of the soil.

Table 4.3.2.1. **Effect of irrigation, FYM and fertilizers on available nitrogen, phosphorus, potassium and organic carbon content of soil**

Treatments	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})	Organic Carbon (per cent)
Irrigation				
a_1	208.76	51.20	101.15	0.61
a_2	212.02	51.07	99.50	0.59
a_3	212.20	51.27	99.61	0.54
a_4	201.40	48.99	98.07	0.47
$F_{3,30}$	1.06	3.01*	9.23**	34.72**
SE	4.90	0.63	0.42	0.01
CD	—	1.83	1.20	0.03
FYM				
b_1	211.19	50.58	99.42	0.52
b_2	206.00	50.69	99.74	0.59
$F_{1,30}$	1.12	0.04	0.66	45.01**
SE	3.46	0.45	0.29	0.01
CD	—	—	—	—
Fertilizer				
c_1	207.48	51.03	99.67	0.56
c_2	209.74	50.24	99.49	0.55
$F_{1,30}$	0.21	1.57	0.20	1.26
SE	3.46	0.45	0.29	0.01
CD	—	—	—	—

** Significant at 1 per cent level   * Significant at 5 per cent level

Table 4.3.2.2. **Interaction effect of irrigation, FYM and fertilizers on available nitrogen, phosphorus, potassium and organic carbon content of soil**

Treatments	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})	Organic Carbon (per cent)
a_1b_1	210.60	51.49	101.57	0.55
a_1b_2	207.37	50.91	100.73	0.66
a_2b_1	214.11	50.71	98.59	0.56
a_2b_2	209.93	51.43	100.41	0.63
a_3b_1	217.68	51.13	99.34	0.50
a_3b_2	206.72	51.41	99.88	0.57
a_4b_1	202.82	48.99	98.19	0.45
a_4b_2	199.98	49.00	97.94	0.48
$F_{3,30}$	0.16	0.18	1.87	2.24
SE	6.93	0.90	0.59	0.02
CD	—	—	—	—
a_1c_1	209.13	51.38	101.15	0.62
a_1c_2	208.39	51.03	101.15	0.60
a_2c_1	213.52	51.98	100.18	0.60
a_2c_2	210.52	50.17	98.82	0.59
a_3c_1	204.66	51.45	99.57	0.55
a_3c_2	219.73	51.10	99.64	0.53
a_4c_1	202.59	49.33	97.76	0.47
a_4c_2	200.21	48.66	98.37	0.47
$F_{3,30}$	0.77	0.30	0.99	0.21
SE	6.93	0.90	0.59	0.02
CD	—	—	—	—

4.3.2.3 Available phosphorus (Table 4.3.2.1 and 4.3.2.2)

Irrigation treatments slightly affected the available phosphorus status of soil. P availability in soil was maximum with lowest level of irrigation (51.27 kg ha^{-1}) which was on par with other irrigation levels. Generally, available phosphorus content of soil was more under irrigated condition than under rainfed condition. The lowest P content was recorded (48.99 kg ha^{-1}) in rainfed plots.

Effect of farm yard manure, chemical fertilizer and interaction effects of the treatments were non significant with regard to the available P status of soil.

4.3.2.4 Available potassium (Table 4.3.2.1 and 4.3.2.2)

Irrigation levels significantly affected the available potassium status of the soil. Highest irrigation treatment resulted in highest available K content in soil (101.5 kg ha^{-1}). Lowest available K content was found with the rainfed treatment (98.07 kg ha^{-1}). Other treatments were on par.

There was no significant effect on the available K status of soil by organic manure or fertilizer treatments and the interaction between the two; upto doses equal to their recommended levels.

4.4 Quality studies

4.4.1 Crude protein content (Table 4.4.1.1 and 4.4.1.2)

Irrigation had significant effect on the crude protein content of the fodder. Highest irrigation treatment showed maximum crude protein content (8.82 per cent) which was on par with other irrigation treatments. Rainfed treatment recorded the least crude protein content (8.16 per cent).

Table 4.4.1.1. **Effect of irrigation, FYM and fertilizers on crude protein content, crude fibre content and K : (Ca + Mg) ratio of congosignal on dry weight basis**

Treatments	Crude protein (per cent)	Crude fibre (per cent)	K : (Ca + Mg) ratio
Irrigation			
a_1	8.82	29.38	1.03
a_2	8.87	30.19	1.04
a_3	8.52	30.18	0.85
a_4	8.16	30.16	0.92
$F_{3,30}$	9.76**	1.21	4.43*
SE	0.10	0.36	0.05
CD	0.30	—	0.13
FYM			
b_1	8.69	29.68	1.00
b_2	8.50	30.28	0.92
$F_{1,30}$	3.58	2.68	2.95
SE	0.07	0.26	0.03
CD	—	—	—
Fertilizer			
c_1	8.63	30.04	0.98
c_2	8.56	29.92	0.94
$F_{1,30}$	0.36	0.12	0.57
SE	0.07	0.26	0.03
CD	—	—	—

** Significant at 1 per cent level * Significant at 5 per cent level

Table 4.4.1.2. **Interaction effect of irrigation, FYM and fertilizers on crude protein, crude fibre and K : (Ca + Mg) ratio of congosignal on dry weight basis**

Treatments	Crude protein (per cent)	Crude fibre (per cent)	K : (Ca + Mg) ratio
a_1b_1	8.88	29.07	1.05
a_1b_2	8.77	29.70	1.02
a_2b_1	8.97	29.63	1.06
a_2b_2	8.77	30.75	1.03
a_3b_1	8.68	30.28	0.98
a_3b_2	8.36	30.08	0.72
a_4b_1	8.25	29.75	0.91
a_4b_2	8.07	30.57	0.92
$F_{3,30}$	0.17	0.61	1.91
SE	0.15	0.57	0.06
CD	—	—	—
a_1c_1	8.84	29.00	1.07
a_1c_2	8.80	29.77	0.99
a_2c_1	9.00	30.88	1.09
a_2c_2	8.74	29.50	1.00
a_3c_1	8.32	29.85	0.76
a_3c_2	8.72	30.52	0.93
a_4c_1	8.33	30.43	0.99
a_4c_2	7.99	29.88	0.85
$F_{3,30}$	2.50	2.03	2.36
SE	0.15	0.51	0.06
CD	—	—	—

Organic manure and chemical fertilizer had no significant effect on the crude protein content of fodder. Interaction effects of the treatments also were found to be non significant with regard to the crude protein content of fodder.

4.4.2 Crude fibre content (Table 4.4.1.1 and 4.4.1.2)

None of the irrigation, FYM or fertilizer treatments, either alone or in combination. significantly affected the crude fibre content of fodder.

4.4.3 K : (Ca + Mg) ratio (Table 4.4.1.1 and 4.4.1.2)

Irrigation levels influenced the K : (Ca + Mg) ratio of the fodder. The ratio was highest with irrigation at 45 mm CPE (1.04) which was on par with irrigation at 30 mm CPE and rainfed. Irrigation at 60 mm CPE recorded the lowest K : (Ca + Mg) ratio (0.85).

Organic manures and chemical fertilizers had no significant effect on K : (Ca + Mg) ratio. Interaction effects of irrigation, organic manure and fertilizers were also non significant.

4.5 Soil moisture studies

4.5.1 Field water use efficiency (Table 4.5.1.1 and 4.5.1.2)

Irrigation had slight negative influence on the field water use efficiency. Rainfed treatment recorded the highest field water use efficiency (17.03 kg ha^{-1} mm^{-1}). The plots treated with different levels of irrigation showed almost the same field water use efficiency.

Chemical fertilizers also significantly affected the field water use efficiency.

Table 4.5.1.1. **Effect of irrigation, FYM and fertilizers on field water use efficiency of congosignal**

Treatments	Water use efficiency (kg ha^{-1} mm^{-1})
Irrigation	
a_1	15.16
a_2	15.73
a_3	15.65
a_4	17.03
$F_{3,30}$	4.11*
SE	0.39
CD	1.14
FYM	
b_1	15.85
b_2	15.94
$F_{1,30}$	0.05
SE	0.28
CD	—
Fertilizer	
c_1	16.71
c_2	15.08
$F_{1,30}$	17.22**
SE	0.28
CD	0.81

** Significant at 1 per cent level * Significant at 5 per cent level

Table 4.5.1.2. Interaction effect, FYM and fertilizers on field water use efficiency of congosignal

Treatments	Water use efficiency ($kg\ ha^{-1}\ mm^{-1}$)
a_1b_1	15.04
a_1b_2	15.28
a_2b_1	15.43
a_2b_2	16.03
a_3b_1	16.15
a_3b_2	15.15
a_4b_1	16.76
a_4b_2	17.30
$F_{3,30}$	0.89
SE	0.56
CD	—
a_1c_1	16.23
a_1c_2	14.09
a_2c_1	16.46
a_2c_2	15.00
a_3c_1	16.47
a_3c_2	14.83
a_4c_1	17.69
a_4c_2	16.38
$F_{3,30}$	0.21
SE	0.56
CD	—

The water use efficiency of crop received 100 per cent of package of practices recommendation was significantly higher than that received 50 per cent of package of practices recommendation.

The effect of organic manure alone and irrigation, organic manure and fertilizers in combination were not significant with regard to the field water use efficiency.

4.5.2 Soil moisture depletion pattern (Table 4.5.2.1 and 4.5.2.2)

Soil moisture depletion from the top 0-30 cm layer of the profile was significantly affected by the irrigation treatments. Moisture depletion was highest uner medium level of irrigation (81.39 per cent). Rainfed treatment recorded the lowest soil moisture depletion (74.83 per cent) from 0 - 30 cm depth of soil, which was remarkably lower than that from the irrigated plots. Different irrigation levels also varied significantly among them with regard to moisture depletion from 0 - 30 cm layer of soil.

Fertilizer application recorded a significant influence on the soil moisture depletion from the top 0-30 cm soil layer. Moisture depletions were remarkably high from the plots receiving higher dose of chemical fertilizers (79.53 per cent) than those receiving lower dose of fertilizers (77.39 per cent).

FYM alone or in combination with irrigation had no significant effect on the depletion of moisture from the surface 30 cm layer of soil.

Interaction of irrigation with fertilizers slightly affected the moisture depletion from the 0 - 30 cm layer of soil. Medium level of irrigation and higher level of fertilizers recorded maximum water depletion (82.69 per cent)

Table 4.5.2.1. **Effect of irrigation, FYM and fertilizers on soil moisture depletion pattern of congosignal**

Treatment	Soil moisture depletion from 0-30 cm depth (%)	Soil moisture depletion from 30-60 cm depth (%)	Soil moisture depletion from 60-90 cm depth (%)
Irrigation			
a_1	80.81	17.61	1.58
a_2	81.39	17.27	1.33
a_3	76.80	21.05	2.15
a_4	74.83	23.40	1.91
$F_{3,30}$	71.29**	96.50**	4.26*
SE	0.37	0.30	0.17
CD	1.08	0.86	0.50
FYM			
b_1	78.08	19.99	1.93
b_2	78.84	19.68	1.55
$F_{1,30}$	4.15	1.07	4.85*
SE	0.27	0.21	0.12
CD	—	—	0.36
Fertilizer			
c_1	79.53	19.02	1.53
c_2	77.39	20.65	1.96
$F_{1,30}$	32.58**	30.26**	6.11*
SE	0.27	0.21	0.12
CD	0.77	0.61	0.36

** Significant at 1 per cent level * Significant at 5 per cent level

Table 4.5.2.2. **Interaction effect of irrigation, FYM and fertilizers on soil moisture depletion pattern of congosignal**

Treatment	Soil moisture depletion from 0-30 cm depth (%)	Soil moisture depletion from 30-60 cm depth (%)	Soil moisture depletion from 60-90 cm depth (%)
a_1b_1	80.78	17.68	1.54
a_1b_2	80.84	17.55	1.62
a_2b_1	80.70	17.79	1.52
a_2b_2	82.09	16.76	1.15
a_3b_1	76.70	20.61	2.70
a_3b_2	76.91	21.49	1.60
a_4b_1	74.14	23.88	1.98
a_4b_2	75.52	22.92	1.84
$F_{3,30}$	0.93	2.24	2.12
SE	0.53	0.42	0.25
CD	—	—	—
a_1c_1	81.61	17.05	1.34
a_1c_2	80.01	18.18	1.82
a_2c_1	82.69	16.25	1.06
a_2c_2	80.09	18.30	1.61
a_3c_1	78.78	19.55	1.67
a_3c_2	74.83	22.55	2.63
a_4c_1	75.03	23.21	2.04
a_4c_2	74.63	23.59	1.78
$F_{3,30}$	4.05*	3.62*	2.15
SE	0.53	0.42	0.25
CD	1.53	1.22	—

** Significant at 1 per cent level   * Significant at 5 per cent level

which was on par with water depletion from plots received highest levels of irrigation and fertilizers. Rainfed treatment with low fertilizer level showed the least water depletion (74.63 per cent) which was on par with the treatment combinations viz., irrigation at 45 mm CPE and 50 per cent package of practices recommendation and rainfed with 100 per cent package of practices recommendation.

Organic manure and its combination with irrigation had no significant effect on moisture depletion from the surface 30 cm layer of soil.

Soil moisture depletion from 30-60 cm depth of soil showed significant changes with irrigation treatments. Depletion of moisture was maximum in rainfed treatment (23.4 per cent) followed by the least irrigated treatment. Moisture depletions under high and medium levels of irrigation were low and on par (17.61 and 17.27 per cent respectively).

Fertilizer application recorded a significant difference in moisture depletion from the 30-60 cm depth of soil. Moisture depletions from 30 - 60 cm depth of soil were low in plots received higher dose of fertilizers (19.02 per cent) and high in plots received lower dose of fertilizers (20.65 per cent).

Irrigation and fertilizer interaction had a slight negative influence on moisture depletion from 30 - 60 cm depth. Maximum depletion of moisture was observed in rainfed treatment receiving lower fertilizer doses (23.69 per cent) which was significantly higher than all other treatments. Lowest moisture depletion (16.25 per cent) was observed in the combination of irrigation at 45 mm CPE and 100 per cent of package of practices recommendation of fertilizers; which was on par with the moisture depletion from treatment involving irrigation at 30 mm CPE and 100 per cent of package of fertilizers. Irrigations at 30 or 45 mm CPE along with 50 per cent of recommended dose of fertilizers recorded almost the same extent of moisture depletion from 30-60 cm depth of soil. Irrigation at 60 mm CPE in combination with 50 per cent of package of practices recommendation and rainfed with 100 or 50 per cent of fertilizers were on par with regard to the moisture depletion from 30 - 60 cm depth of soil.

Independent effect of FYM and its combination effect with irrigation were found non significant on the moisture depletion from 30 - 60 cm depth.

Irrigation, FYM and fertilizer had slight negative influence on soil moisture depletion from 60 - 90 cm depth. Plots which received lowest irrigation showed maximum moisture depletion (2.15 per cent), which was on par with the moisture depletion under rainfed condition. Moisture depletion from 60 - 90 cm depth was lowest (1.33 per cent) in plots received irrigation at 45 mm CPE, which was on par with the moisture depletion from plots received irrigation at 30 mm CPE.

Higher dose of organic manure showed higher moisture depletion from 60-90 cm depth (1.93 per cent), but, it was on par with moisture depletion under lower dose of FYM (1.55 per cent).

Lower level of fertilizers resulted in significantly higher moisture depletion (1.96 per cent) from 60 - 90 cm depth of soil than higher level of fertilizers ; which recorded a moisture depletion of 1.53 per cent.

Irrigation and FYM, irrigation and fertilizer and FYM and fertilizer interactions showed no significant effect on moisture depletion from 60 - 90 cm depth of soil.

4.6 Root studies

4.6.1 Root length (Table 4.6.1.1 and 4.6.1.2)

Root length recorded slight change with irrigation levels. Medium irrigation produced maximum root length (34.54 cm) which was on par with the highest irrigation treatment (Plate 2). Root length for rainfed crop was the lowest (26.63 cm) which was on par with lowest irrigation level (Plate 3).

There was a slight change in the root length of congosignal with the interaction of irrigation and organic manure treatments. Maximum root length (37.53 cm) was recorded with irrigation at 45 mm CPE and FYM @ 7.5 t ha^{-1} which was on par with the root lengths in treatment combinations viz., irrigation at 30 or 45 mm CPE and FYM @ 5.0 t ha^{-1} and irrigation at 60 mm CPE and FYM @ 7.5 t ha^{-1}. Rainfed treatments at both levels of FYM and least frequent irrigation with 5.0 t ha^{-1} of FYM showed lowest root lengths which were on par.

Independent effects of FYM and fertilizers, their interaction effect and also the interaction effect of irrigation and fertilizers were non significant with regard to the root length of congosignal.

4.6.2 Root weight (Table 4.6.1.1 and 4.6.1.2)

Significant effects of irrigation treatments were observed on the root weight of congosignal. Maximum root weight was recorded for medium level of irrigation (39.73 g) which was on par with that of highest level of irrigation. Rainfed crop showed significant reduction in root weight (27.18 g).

Single effects of FYM and fertilizers as well as interaction effects of irrigation and FYM, irrigation and fertilizer and FYM and fertilizer were non significant with regard to the root weight.

Table 4.6.1.1. **Effect of irrigation, FYM and fertilizers on root length and root weight of congosignal**

Treatments	Root length (cm)	Root weight (g plant^{-1})
Irrigation		
a_1	32.01	39.60
a_2	34.54	39.73
a_3	28.66	33.87
a_4	26.63	27.18
$F_{3,30}$	4.04*	34.74**
SE	1.75	1.01
CD	5.04	2.91
FYM		
b_1	30.77	34.48
b_2	30.15	35.70
$F_{1,30}$	0.13	1.47
SE	1.23	0.71
CD	—	—
Fertilizer		
c_1	30.35	35.83
c_2	30.56	34.36
$F_{1,30}$	0.01	2.13
SE	1.23	0.71
CD	—	—

** Significant at 1 per cent level * Significant at 5 per cent level

Table 4.6.1.2. Interaction effect of irrigation, FYM and fertilizers on root length and root weight of congosignal

Treatments	Root length (cm)	Root weight (g $plant^{-1}$)
a_1b_1	35.05	39.60
a_1b_2	28.97	39.59
a_2b_1	31.55	37.56
a_2b_2	37.53	41.90
a_3b_1	26.40	32.69
a_3b_2	30.92	35.05
a_4b_1	30.08	28.08
a_4b_2	23.17	26.28
$F_{3,30}$	3.81*	1.77
SE	2.47	1.43
CD	7.13	—
a_1c_1	34.12	41.12
a_1c_2	29.90	38.07
a_2c_1	32.62	38.69
a_2c_2	36.47	40.77
a_3c_1	26.90	35.01
a_3c_2	30.42	32.72
a_4c_1	27.78	28.50
a_4c_2	25.47	25.87
$F_{3,30}$	1.37	1.40
SE	2.47	1.43
CD	—	—

* Significant at 5 per cent level

Plate 2. Difference in root length of Congosignal with various irrigation treatments

a. Irrigation at 45 mm CPE and rainfed

b. Irrigation at 30 mm CPE and rainfed


Rainfed
Irrigated
45 mm CPE


Rainfed
Irrigated
30 mm CPE

Plate 3 Treatments recorded the lowest root length in Congosignal

Irrigation at 60 mm CPE and rainfed


Rainfed
Irrigated
60 mm CPE

4.7 Economics of the study

4.7.1 Net income (Table 4.7.1.1 and 4.7.1.2)

Effect of irrigation was visible on the net income. Medium irrigation treatment gave significantly higher net income (40560.50 Rs ha^{-1}). Other irrigation treatments and rainfed treatment gave almost the same net income.

Fertilizer treatments also significantly influenced the net income. Package of practices recommendation of fertilizers gave a higher net income (37538.71 Rs. ha^{-1}) than 50 per cent reduction in recommended fertilizer (32861.71 Rs. ha^{-1}).

FYM alone and the interactions between FYM and irrigation as well as FYM and fertilizers had no significant effect on net income.

4.7.2. Benefit : cost ratio (B : C ratio) (Table 4.7.1.1 and 4.7.1.2)

Irrigation treatments slightly influenced the B : C ratio.B : C ratio was highest in medium irrigated plots (2.11). Lowest B : C ratio was recorded for irrigation at 30 mm CPE (1.16).

Independent effects of organic manure and fertilizers and interaction effects of irrigation, organic manure and fertilizers had no significant effect on the B : C ratio.

4.8 Yield of coconuts

The average annual nut yields of coconut palms in the experimental area were 34.9 and 36.2 nuts $palm^{-1}$ respectively for the periods 1996-97 and 1997-98 (pre-experimental period). During the experimental year it was increased to 39.5 nuts $palm^{-1}$ y^{-1} . The yield data of coconut palms in the experimental area during pre-experimental and experimental period are given in Table 4.8.

Table 4.7.1.1. **Effect of irrigation, FYM and fertilizers on net income and benefit : cost (B : C) ratio of congosignal**

Treatments	Net income (Rs. ha^{-1})	B : C ratio
Irrigation		
a_1	32571.92	1.16
a_2	40560.50	2.11
a_3	34278.58	1.79
a_4	33389.831.86	
$F_{3,30}$	11.60^{**}	52.36^{*}
SE	1068.88	0.06
CD	3086.75	0.16
FYM		
b_1	34849.21	1.76
b_2	35551.21	1.70
$F_{1,30}$	0.43	1.16
SE	755.81	0.04
CD	—	—
Fertilizer		
c_1	37538.71	1.79
c_2	32861.71	1.67
$F_{1,30}$	19.15^{**}	4.10
SE	755.81	0.04
CD	2182.66	—

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4.7.1.2. **Interaction effect of irrigation with FYM and fertilizers on net income and benefit : cost (B : C) ratio of congosignal cultivation**

Treatments	Net income (Rs. ha^{-1})	B : C ratio
a_1b_1	30844.50	1.12
a_1b_2	34299.33	1.21
a_2b_1	39666.50	2.12
a_2b_2	41454.50	2.10
a_3b_1	36069.67	1.93
a_3b_2	32487.50	1.64
a_4b_1	32816.17	1.87
a_4b_2	33963.50	1.85
$F_{3,30}$	1.99	2.05
SE	1511.62	0.08
CD	—	—
a_1c_1	35292.83	1.23
a_1c_2	29851.00	1.10
a_2c_1	42442.83	2.15
a_2c_2	38678.17	2.07
a_3c_1	36593.17	1.85
a_3c_2	31964.00	1.72
a_4c_1	35826.00	1.92
a_4c_2	30953.67	1.80
$F_{3,30}$	0.11	0.06
SE	1511.62	0.08
CD	—	—

Table 4.8. Yield data of coconut palms in the experimental site during pre-experimental and experimental period

Palm No.	Pre-experimental period										Experimental period				
	1996-1997					1997-1998					1998-1999				
	Nov.	Jan.	Mar.	May	Total	Nov.	Jan.	Mar.	May	Total	Nov.	Jan.	Mar.	May	Total
34F	8	14	10	11	43	8	10	12	9	39	9	9	14	10	42
45F	8	6	7	6	27	7	6	10	8	31	8	7	11	12	38
82F	12	9	9	5	35	10	8	10	7	35	9	9	7	10	35
65F	9	12	8	10	39	13	6	9	12	40	10	9	7	13	39
83F	5	8	8	9	30	6	7	9	11	33	7	8	10	9	34
47F	5	10	8	6	29	5	11	7	8	31	7	13	9	10	39
62F	10	6	10	9	35	11	7	9	12	39	14	8	13	11	46
61F	9	12	10	6	37	11	10	9	7	37	11	9	12	8	40
79F	6	14	9	8	37	7	15	8	8	38	5	13	10	11	39
71F	6	12	10	9	37	8	10	12	9	39	9	11	9	14	43
Total	78	103	89	79	349	86	90	95	91	362	89	96	102	108	395

DISCUSSION

5. DISCUSSION

The present investigation was undertaken with the objectives to study the effect of irrigation, farm yard manure and fertilizers on the yield and quality of congosignal grass grown under partial shade; to assess the changes in physico-chemical properties of the soil due to grass cultivation and also to work out the economics of irrigated fodder production in coconut gardens. The results of the experiment, presented in the previous chapter, are discussed hereunder.

5.1 Growth parameters and yield

5.1.1 Plant height

The effects of irrigation, FYM and fertilizers were varying with different harvests as it is clear from Fig. 5.1.1.1. Higher levels of irrigation increased the plant height which may be due to the enhancement of nutrient uptake (Yeh, 1988) and faster rates of regrowth under shaded condition (Wong *et al.*, 1985). FYM application @ 7.5 t ha^{-1} increased the plant height upto the third harvest. This indicated that the residual effect of FYM did not last for more than 135 days (approximately four months). Gupta *et al.* (1988) had noticed a residual effect of FYM in soil for 52 days (nearly two months). At 30 and 45 mm CPE irrigation levels, a higher dose (7.5 t ha^{-1}) of FYM was found to be better in increasing the plant height. But, 5.0 and 7.5 t ha^{-1} of FYM showed the same effect at lowest irrigation level (60 mm CPE) and rainfed condition (Fig. 5.1.1.2)at majority of harvests. This showed that when moisture availability was limited, application of a higher dose of FYM did not produce any favourable effect on the plant height of fodder grass.

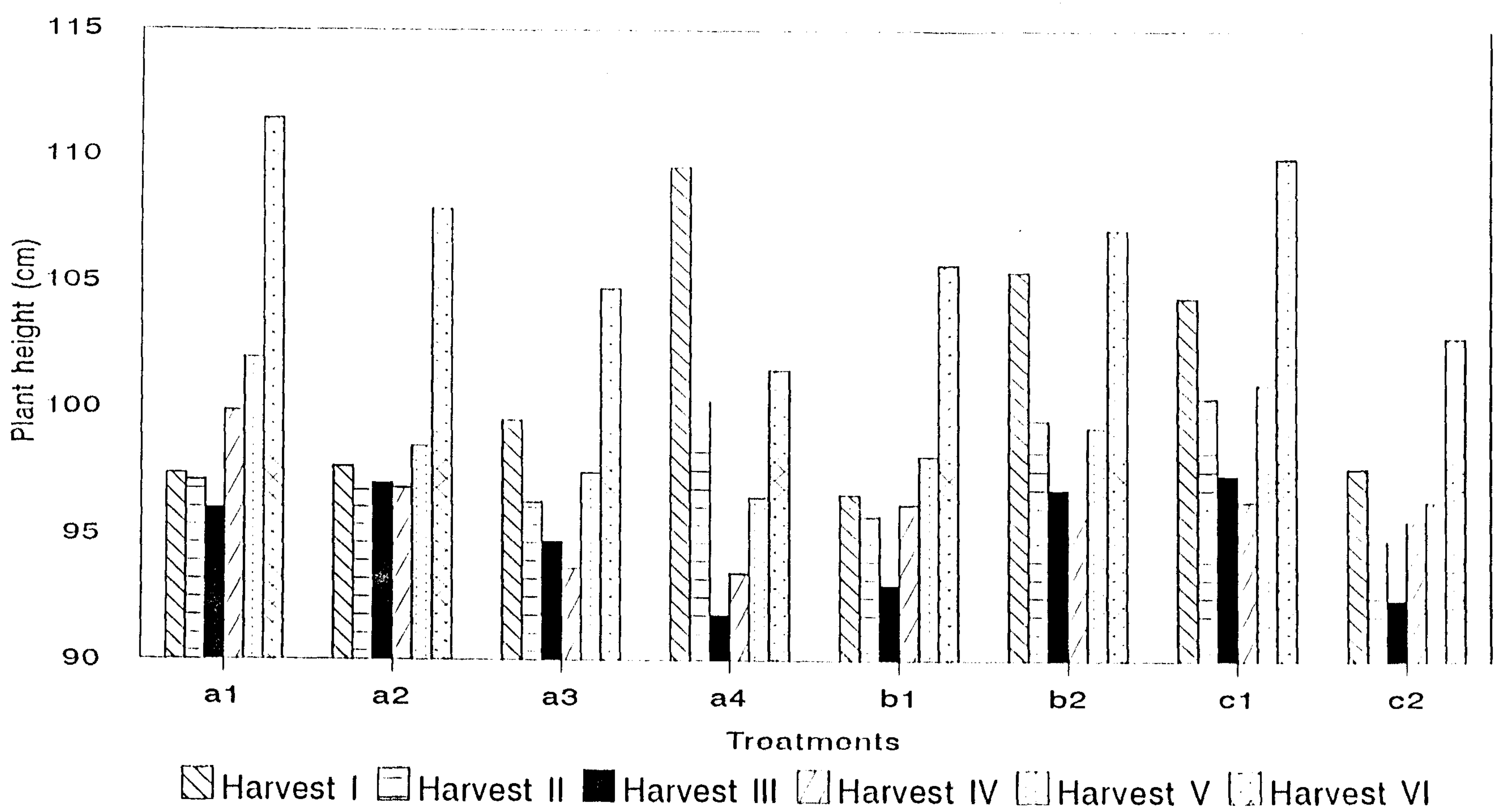
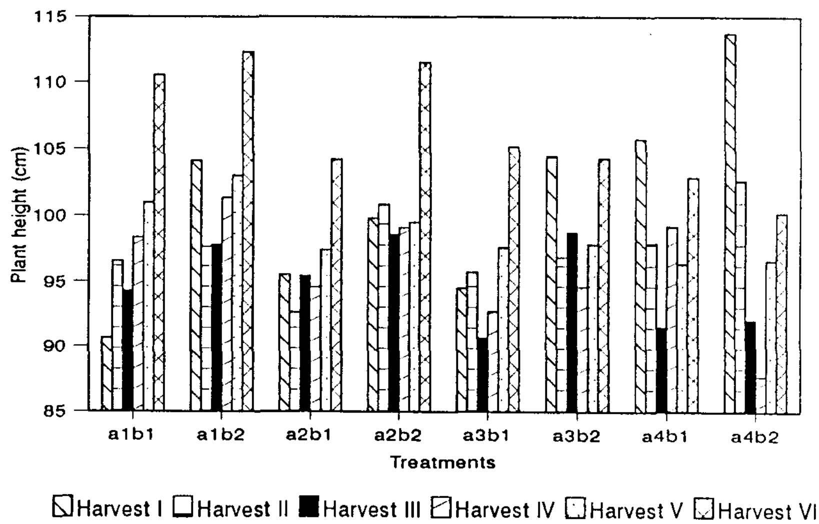


Fig. 5.1.1.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on plant height of congosignal



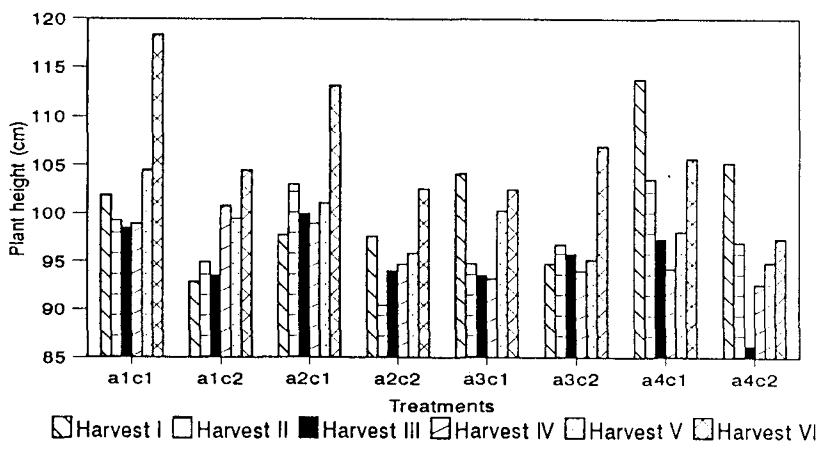


Fig. 5.1.1.2. Interaction effect of irrigation (a), FYM (b) and fertilizers (c) on plant height of congosignal

Plate 4 Best combination of irrigation, FYM and fertilizer levels with regard to the plant height of Congosignal

a. Irrigation at 30 mm CPE + FYM 7.5 t ha^{1} + 100 per cent fertilizers

b. Irrigation at 45 mm CPE + FYM 7.5 t ha^{1} + 100 per cent fertilizers


$a_1b_2c_1$


$a_2b_2c_1$

A full dose of chemical fertilizers as per the package of practices recommendations was obviously superior in increasing the plant height. This indicated that 50 per cent reduction in fertilizers was inadequate for enhancing the regrowth of congosignal grass. Although there was a varying trend in the interaction effect of irrigation and fertilizers, the general observation was that higher irrigation levels in combination with higher fertilizer dose increased the height of plants (Fig. 5.1.1.2). This was in agreement with the findings of Beaty *et al.* (1977), Yeh (1988) and Hong and Hsu (1993). The treatment combinations which produced maximum plant height in congosignal are shown in plate 4.

5.1.2 Tiller number hill^{-1}

Tiller number was higher in most frequently irrigated plots than that in least irrigated or rainfed plots in all harvests except the first two harvests (Fig. 5.1.2.1). Increased moisture availability and reduced soil temperature might have triggered the tiller production in irrigated plots. During the first two harvests, rainfall was available in plenty and hence the rainfed plots recorded higher tiller production. Higher level of FYM significantly increased the tiller number hill^{-1} upto the fourth harvest, beyond which FYM showed no residual effect. Various levels of irrigation along with 7.5 t of FYM ha^{-1} significantly increased the tiller production than rainfed treatments together with any of the two FYM levels (Fig. 5.1.2.2). The tiller production did not vary widely between 100 per cent and 50 per cent of fertilizer doses in first, second and fifth harvests. Best treatment combinations with regard to tiller number hill^{-1} are shown in plate 5.

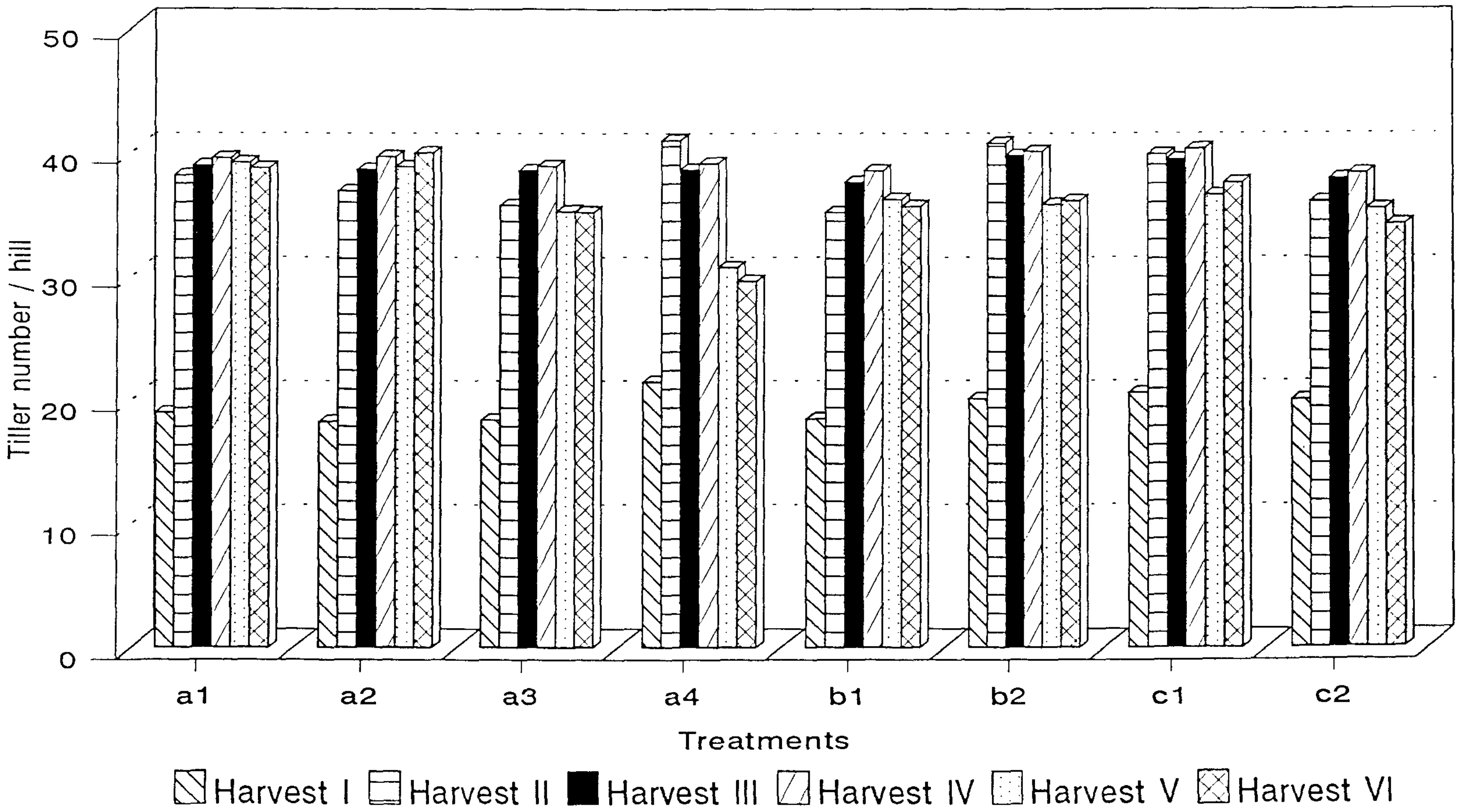
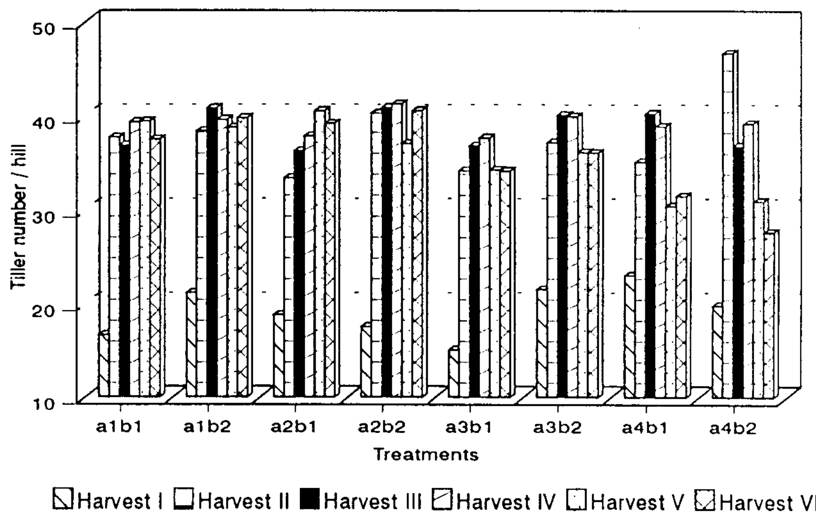


Fig. 5.1.2.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on tiller number per hill of congosignal



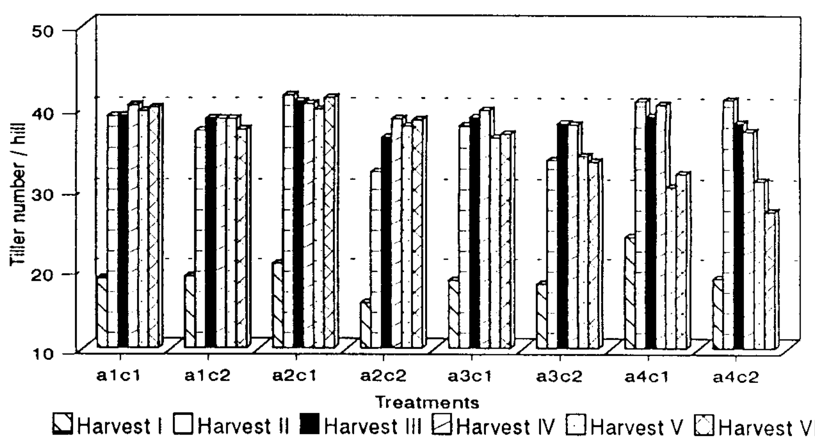


Fig. 5.1.2.2. Interaction effect of irrigation (a), FYM (b) and fertilizers (c) on tiller number per hill of congosignal

Plate 5 Best combination of irrigation, FYM and fertilizer levels with regard to the tiller number $hill^{-1}$ of Congosignal

a. Irrigation at 30 mm CPE + 7.5 t ha^{-1} FYM + 100 per cent fertilizers

b. Irrigation at 45 mm CPE + 7.5 t ha^{-1} FYM + 50 per cent fertilizers


$a_1b_2c_1$


$a_2b_2c_2$

5.1.3 Leaf : stem ratio

In most of the harvests leaf : stem ratio was high with higher levels of irrigation and fertilizers. Leaf : stem ratio was lowest in rainfed plots. This may be due to the inadequacy of moisture which restricts the proper uptake of nutrients and active growth of plants. The recommended fertilizer dose was superior to 50 per cent less fertilizer level in increasing the leaf : stem ratio.

Variable interaction effects were noticed on the leaf : stem ratio with irrigation, FYM and fertilizers. Interactions of treatments were visible only in the last three harvests. Under higher levels of irrigation, the two FYM treatments were equally good. The combination of lowest irrigation and higher FYM treatments produced the lowest leaf : stem ratio. In rainfed plots, low level of FYM produced a high leaf : stem ratio. Hence, it is difficult to point out any specific interaction effect of irrigation with FYM on the leaf : stem ratio. The leaf : stem ratio was found to be decreasing significantly with 50 per cent reduction in fertilizers. Nitrogen and potassic fertilizers were reported to be having little or no effect on the leaf : stem ratio (Yeh, 1988 and Williams and Hanna, 1995 respectively). The present finding is not in accordance with these reports i,e, when NPK dose was increased from 75 : 25 : 25 kg ha^{-1} to 150 : 50 : 50 kg ha^{-1}, the leaf : stem ratio was increased by 19 per cent.

5.1.4 Leaf Area Index (LAI)

Irrigation and fertilizers had a favourable effect on the Leaf Area Index (Fig. 5.1.4.1) of congosignal. In the first, second and fifth harvest, FYM @ 7.5 t ha^{-1} increased the LAI considerably. The favourable effect of fertilizers

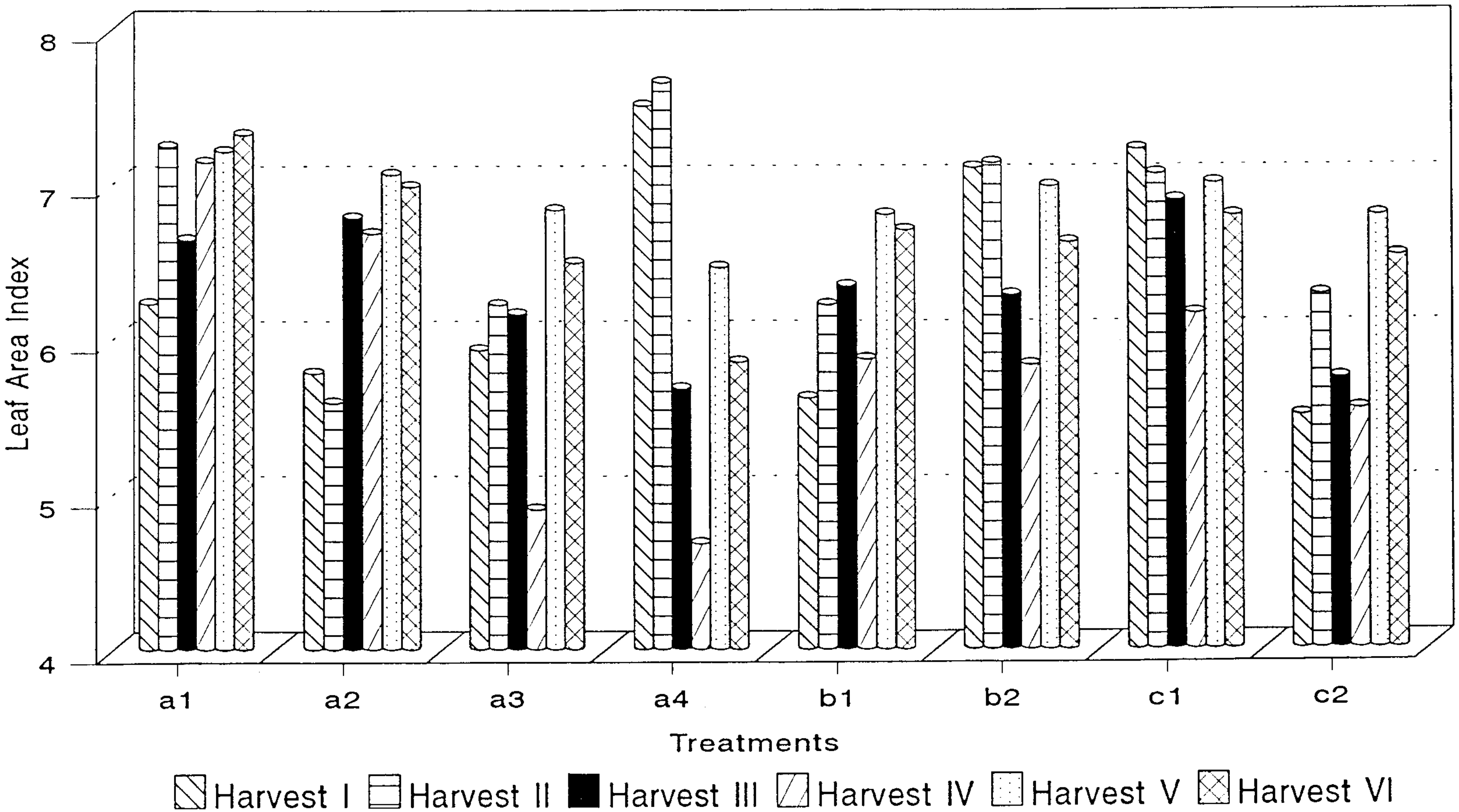
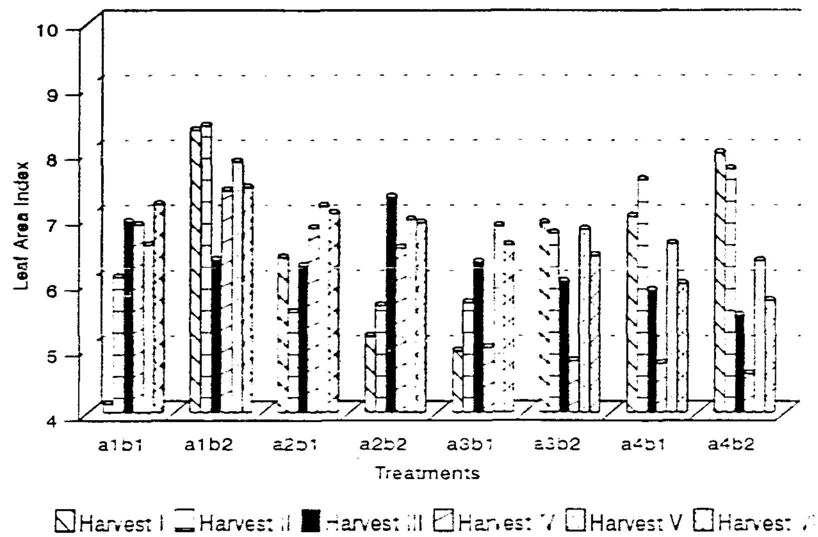


Fig. 5.1.4.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on Leaf Area Index of congosignal



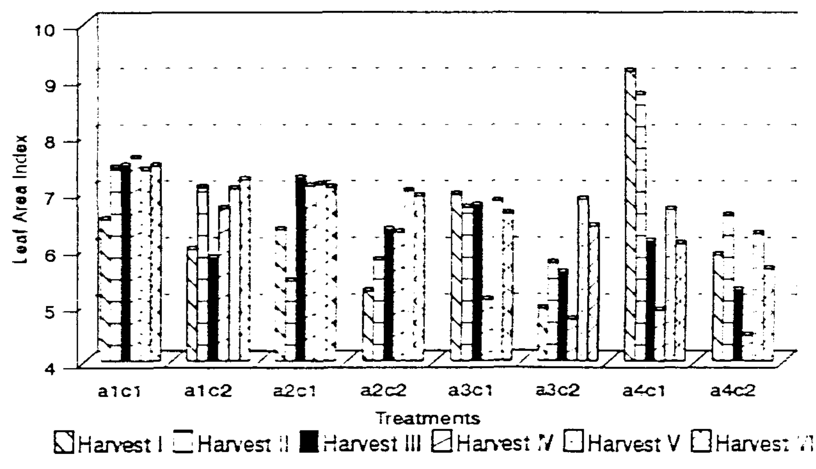


Fig. 5.1.4.2. Interaction effect of irrigation (a), FYM (b) and fertilizers (c) on Leaf Area Index of congosignal

on LAI was supported by the finding of Munegowda *et al.* (1989) and that of FYM by Hussein (1969).

Interaction of high irrigation level with high level of FYM increased the LAI (Fig. 5.1.4.2). Under less frequent irrigation treatments (45 and 60 mm CPE), 100 and 50 per cent of recommended fertilizers were found to have similar influence on the LAI. In rainfed plots, a decrease in the recommended dose of fertilizers reduced the LAI considerably. In short, high levels of irrigation along with higher doses of FYM and fertilizers resulted in an increase in LAI which may be due to better nutrient uptake and the resultant growth improvement.

5.1.5 Green fodder yield

All irrigation levels under consideration (irrigations at 30, 45 and 60 mm CPE) showed a significant increase in the green fodder yield over the rainfed control; except for the first and second harvests (Fig. 5.1.5.1). The increase in fodder yield with irrigation was in confirmity with the reports of Vanek (1974), Filho (1977), Tarmaev (1977), Gill and Malik (1983) and Bhatnager (1995). Higher levels of FYM alone did not result in any remarkable increase in green fodder yield, but the recommended dose of fertilizers markedly increased the yields over 50 per cent less fertilizer level. Higher dose of fertilizers, especially nitrogen was proved to be increasing the herbage yield considerably by many workers (Younis and Agabawi, 1967; Baijvade *et al.*, 1988 and Dwivedi *et al.*, 1991). This showed that when nutrients applied were more, more uptake occured resulting in a higher yield.

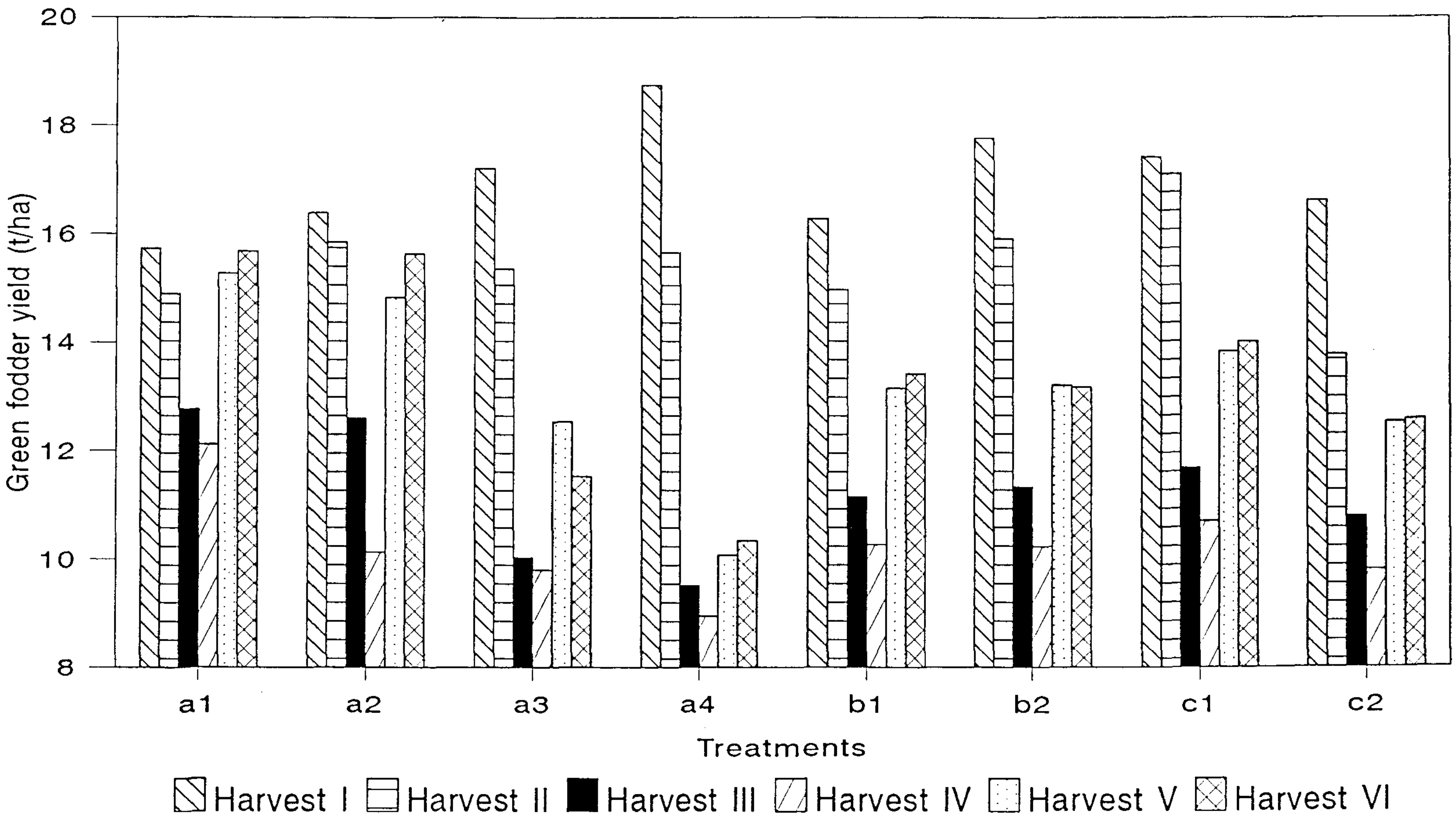
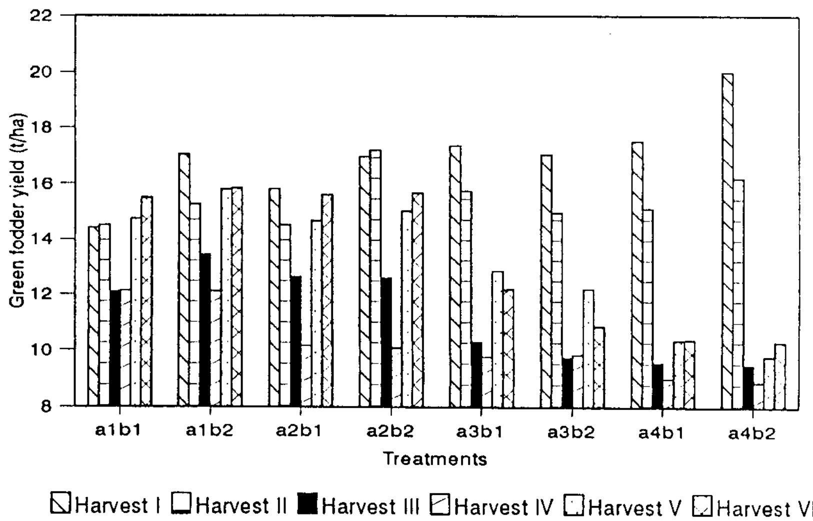


Fig. 5.1.5.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on green fodder yield of congosignal



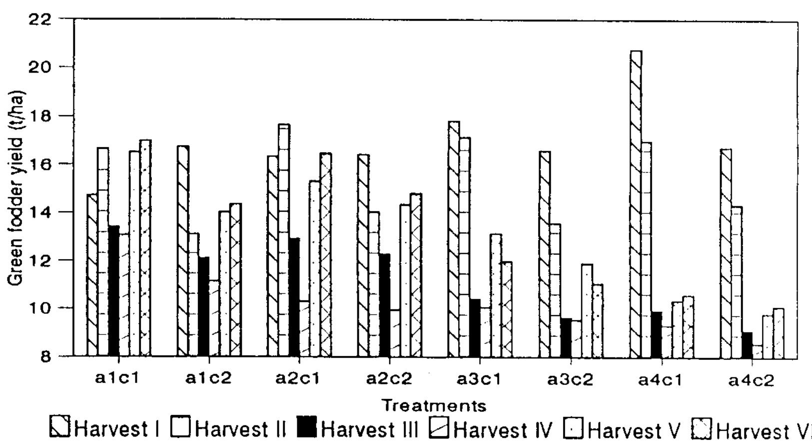


Fig. 5.1.5.2. Interaction effect of irrigation (a), FYM (b) and fertilizers (c) on green fodder yield of congosignal

Irrigation along with FYM application increased the green fodder yield (Fig. 5.1.5.2). Both levels of FYM (5.0 and 7.5 t ha^{-1}) were equally good when all the harvests were considered together. In rainfed treatments, high level of FYM was found to be superior in increasing green fodder yields. In the rainfed crop, during the last three harvests, no significant difference in yield was obtained with the two levels of fertilizers. This indicated that the effect of various levels of chemical fertilizers were fully expressed under irrigated condition. In other words, the response of rainfed crop to fertilizers was less.

5.1.6 Dry fodder yield

As in the case of green fodder yield, dry fodder yield was also high under irrigated condition. This also was a clear indication of better nutrient uptake, growth and yield of fodder grass under irrigated condition. The findings of Herrera *et al.* (1985), Muldoon (1986) and Mansfield *et al.* (1990) supported the result. In all the harvests, the rainfed crop recorded the minimum dry matter yield (Fig. 5.1.6.1). FYM alone (upto 7.5 t ha^{-1}) was not improving the dry fodder yields. Sharma *et al.* (1992) had reported that FYM @ 10 t ha^{-1} alone increased the dry fodder yield in *Brachiaria ruziziensis* upto three years. FYM application in combination with irrigation had a favourable effect on the dry fodder yield. Under rainfed condition, the performances of crop receiving 5.0 and 7.5 t ha^{-1} of FYM were almost similar. Fertilizer application had a clear influence on the dry matter yield. Higher dose of fertilizers increased the dry fodder yields significantly. Higher dry matter production with increased fertilizer application was reported by many workers (Cautaruth *et al.*, 1985 ; Singh, 1987 ; Maiti *et al.*, 1988 ; Costa, 1989 and Pamo, 1991). The response of crop to fertilizers in terms of dry fodder yield was found to be boosted under irrigated conditions (Fig. 5.1.6.2). This may be due to higher nutrient uptake under irrigated conditions. In rainfed crop, full dose of chemical fertilizers gave the highest dry fodder yields. The best treatment combinations which produced the maximum green fodder and dry fodder yields are shown in plate 6.

5.2 Uptake studies

5.2.1 Uptake of nitrogen

Higher levels of irrigation (30 and 45 mm CPE) increased the nitrogen uptake by congosignal grass. Available forms of nitrogen in soil reach the root surface mainly by mass flow. A continuous film of moisture is a must for it. Hence, frequent irrigations resulted in better movement of ions to the root surface and thus the uptake was enhanced. Rainfed treatment resulted in the least nitrogen uptake. FYM upto 7.5 t ha^{-1}, had no favourable effect on the uptake of nitrogen. Puranik *et.al.* (1978) had reported that FYM application @ 11.2 t ha^{-1} increased the herbage nitrogen content. Higher levels of fertilizers were observed to be superior to lower levels in increasing the nitrogen uptake. This observation was supported by the studies of Johnson and Cumminis (1967),Gupta and Gupta (1976) and Singh (1987). This indicated that when more fertilizer nitrogen was added to soil, the uptake was favoured.

Highest level of nitrogen uptake was seen in treatment combinations of 7.5 t ha^{-1} of FYM and higher levels of irrigation. Higher irrigation levels might

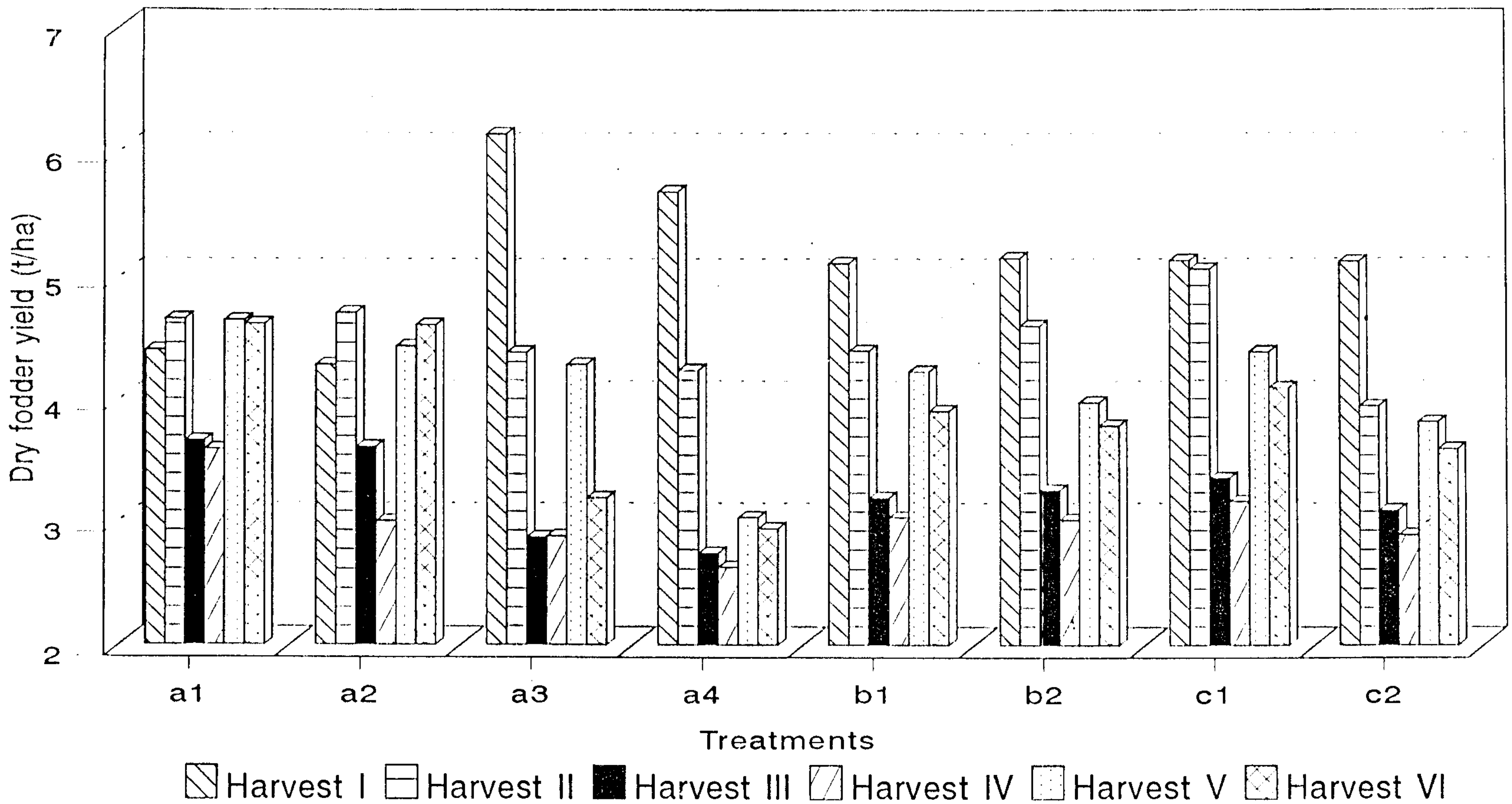
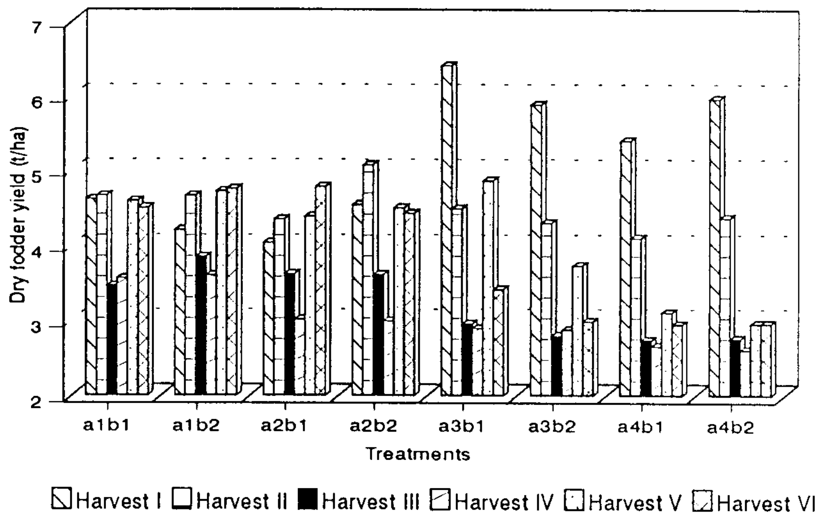


Fig. 5.1.6.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on dry fodder yield of congosignal



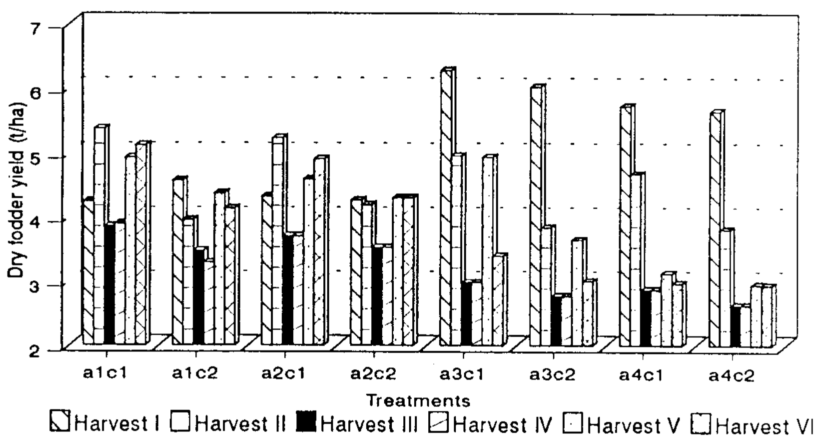


Fig. 5.1.6.2. Interaction effect of irrigation (a), FYM (b) and fertilizers (c) on dry fodder yield of congosignal

Plate 6 Best combination of irrigation, FYM and fertilizer levels with regard to the green and dry fodder yield of Congosignal

a. Irrigation at 30 mm CPE + 5 t ha^{-1} FYM + 100 per cent fertilizers

b. Irrigation at 45 mm CPE + 5 t ha^{-1} FYM + 100 per cent fertilizers


$a_1b_1c_1$


$a_2b_1c_1$

have supplied ample amount of moisture for increased microbial activity; which might have resulted in rapid decomposition of organic manure and better mineralization of organic nitrogen. This favoured the nitrogen uptake under irrigated condition. Under rainfed and least irrigated conditions, both levels of FYM resulted in less uptake of nitrogen. When the irrigation frequency was more, application of 100 per cent of recommended fertilizers was better. Rainfed condition and lower fertilizer levels resulted in the least nitrogen uptake. This indicated that continuous moisture supply at adequate levels throughout the crop period was a must for proper nitrogen uptake.

5.2.2 Uptake of phosphorus

Phosphorus uptake was also found to be higher at 30 mm CPE level of irrigation. Better moisture status of soil might have enhanced the activity of P solubilizing microflora making it readily available to the crop. Also in soil, phosphate ions reach the root surface mainly by diffusion. The rate of diffusion being directly proportional to the soil moisture content, increased irrigation resulted in the diffusion of more phosphate ions to root surface and thus in a better uptake of P. Lowest uptake was seen in the rainfed crop. Full dose of recommended fertilizers increased P uptake i.e., when more fertilizer P was applied to soil, the uptake was increased. The levels of FYM did not influence P uptake significantly. Uptake of phosphorus was reported to be higher with the application of fertilizers in the presence of FYM (Holt and Zentner, 1985; Mathur, 1984 and Srinivasan, 1992). But in this experiment, interaction effects of irrigation, FYM and fertilizers had little effect on phosphorus uptake.

5.2.3 Uptake of potassium

As in the case of phosphorus uptake, potassium uptake was also increased with irrigation and fertilizer application. Potassium ions in soil reach the root surface mainly through mass flow and diffusion, for which water is necessary. Hence, irrigation increased the uptake of K. Supply of readily available K through chemical fertilizer also enhanced the uptake. Rainfed crop had the lowest potassium uptake. Stimulating effect of chemical fertilizers on potassium uptake was reported by Steel and Whiteman (1980). Irrigation + FYM interactions did not produce any favourable effect on the uptake of potassium by congosignal grass in the present study.

5.2.4 Uptake of calcium

Higher irrigation levels and increased doses of N, P and K fertilizers favoured the calcium uptake. This may be attributed to the better movement of calcium ions to the root surface in the presence of adequate soil moisture. N, P and K at the recommended doses improved the plant growth; which automatically resulted in better Ca uptake. FYM and mineral nitrogen fertilizer application were reported to be increasing the Ca uptake by Naik and Ballal (1968) and Mohd. Najib and Hassan (1985).

5.2.5 Uptake of Magnesium

Magnesium ions reach the root surface maily by way of mass flow which is favoured by increased moisture content in the soil. Hence, irrigation had a positive effect on the uptake of Mg by the crop. Rainfed treatment recorded the lowest uptake of Mg. Full dose of recommended fertilizers was found to increase the uptake of magnesium probably due to the better growth rate of the crop by high N, P and K application. FYM had no impact on Mg uptake upto 7.5 t ha^{-1}. FYM and nitrogen fertilizers were reported to enhance Mg uptake by Naik and Ballal (1968) and Mohd. Najib and Hassan (1985).

5.3 Soil Physico-chemical Properties

5.3.1 Physical Properties

Irrigation was found to be decreasing the bulk density of soil. This may be due to the enhanced root growth by adequate moisture supply; which increased the soil porosity. The addition of 7.5 and 5.0 t ha^{-1} of FYM did not improve the bulk density. Klute and Jacob (1949) opined that heavy organic matter addition was necessary for bringing about any significant change in soil bulk density. Fertilizer treatments were found to decrease the bulk density of soil. This also may be attributed to the better root growth. Stauffer (1955) and Manickam and Venkataramanan (1972) had noticed no significant influence of fertilizers on the bulk density of soil. Misra *et. al* (1982) and Ingelmo and Caudrado (1986) observed that long term cultivation of grasses decreased the apparent specific gravity (bulk density) of soils. Irrigation and 7.5 t ha^{-1} of FYM had a favourable interaction effect on soil bulk density.

In the present study, irrigation and fertilizer application had increased the water holding capacity of soil, which may be due to the improvement of soil porosity by grass cultivation. Addition of 7.5 t ha^{-1} of FYM increased the water holding capacity of soil. This was in close confirmity with the results obtained by Salter and Williams (1963) and Verma(1991). Among the treatment combinations, irrigation at various levels + 7.5 t of FYM ha^{-1} were better in improving the water holding capacity of soil. Soil in the rainfed plots receiving lower dose (5.0 t ha^{-1}) of FYM recorded the least water holding capacity. These showed the better ability of organic matter to hold water in the soil.

Soil porosity showed the same trend as that of water holding capacity. Irrigation as well as FYM and fertilizer application increased the porosity of soil. Increased nutrient supply through FYM and fertilizers improved the root growth of the crop which in turn improved the soil porosity. The single effects of the treatments on the soil physical properties are clear from Fig. 5.3.1.1 and the interaction effects of treatments are shown in Fig. 5.3.1.2.

5.3.2 Chemical properties of soil

5.3.2.1 Organic carbon

High levels of irrigation and FYM were found to improve the soil organic carbon content. Continuous cultivation of *Brachiarica ruziziensis* was reported to be increasing the soil organic carbon content by Silva *et al.* (1997). Root decay and decay of older shoots and leaves added to the organic carbon content of soil.

5.3.2.2 Available nitrogen

Available nitrogen content of soil did not show any significant increase after the experiment. This was possibly due to the better uptake of nitrogen from soil by the crop. Under irrigated condition, the crop might have utilized most of the available nitrogen in soil for its growth. FYM was reported to be increasing the available nitrogen content of the soil by Singh and Jaiprakash (1968), Gupta *et al.* (1988) and Shinde and Gowade (1992). Application of fertilizers, especially nitrogen, was found to increase the available nitrogen content of soil by Bhavanase *et al.* (1992).

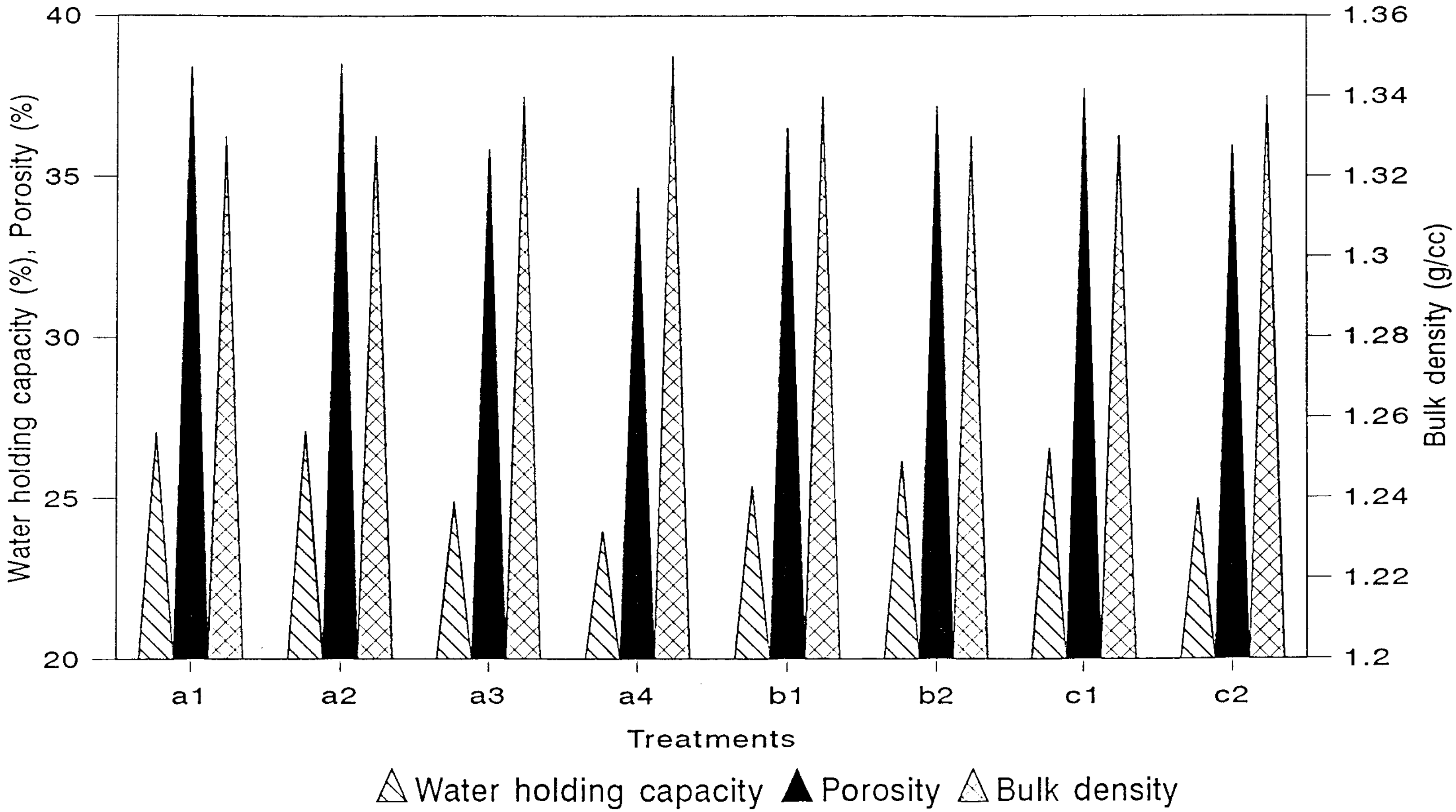
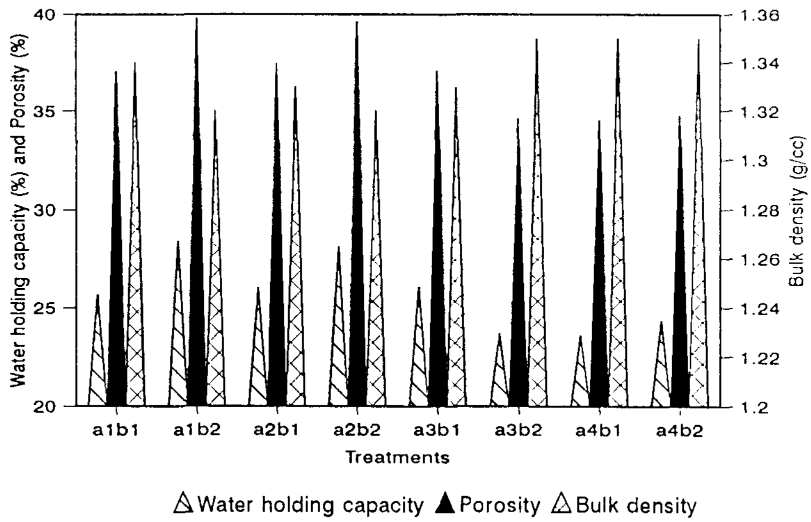


Fig. 5.3.1.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on bulk density, water holding capacity and porosity of soil



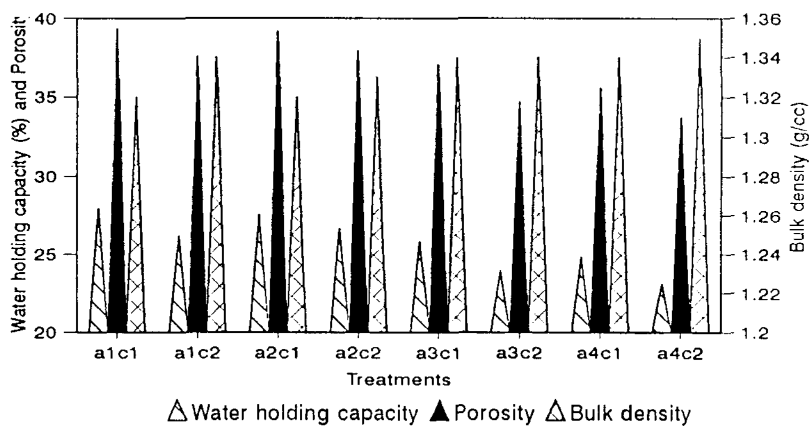


Fig. 5.3.1.2. Interaction effect of irrigation (a), FYM (b) and fertilizers (c) on water holding capacity, porosity and bulk density of soil

5.3.2.3 Available phosphorus

Irrigation had a slight effect on the available P status of soil. Soil P content was higher in irrigated plots after the experiment. This may be due to the increased activity of P solubilizing micro-organisms under irrigated conditions and better water solubility of applied P fertilizer (mussoriphos). There are many reports of increased P content of soil by FYM application (Dalton *et al.*, 1952; Chellamuthu *et al.*, 1988 and Shinde and Gowade, 1992). But, no such effect is noticed in the present investigation because, heavy doses of bulky organic manure are required to bring about a significant change in the available P status of soil. NPK applied @ 150 : 50 : 50 kg ha^{-1} did not produce any appreciable increase in the available P status of soil. This may be either due to the better uptake by the crop or increased fixation in soil; thus making it unavailable.

5.3.2.4 Available potassium

Irrigated plots showed a higher content of available potassium in soil than the rainfed treatment. This was probably due to the better release of fixed K in soil in presence of adequate moisture. Eventhough there are reports regarding better available K status of soil due to fertilizer (Nagi *et al.*, 1981) and FYM application (Sharma and Arora, 1988 and Shinde and Gowade, 1992); no such effect was visible in the present experiment upto NPK dose of 150 : 50 : 50 kg ha^{-1} and FYM application @ 7.5 t ha^{-1}.

The effects of various levels of treatments on soil chemical properties are shown in Fig. 5.3.2.1.

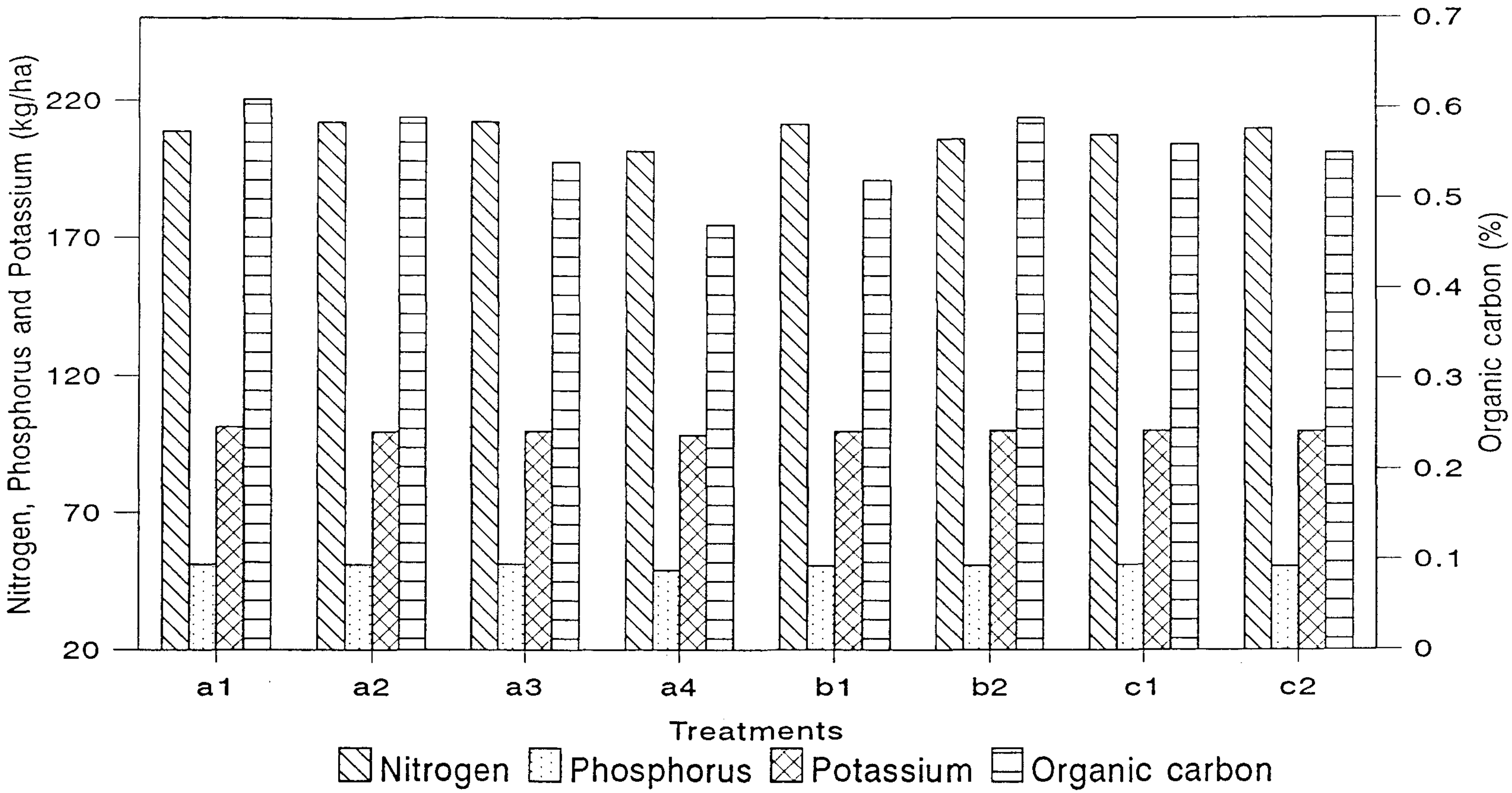


Fig. 5.3.2.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on available nitrogen, phosphorus, potassium and organic carbon content of soil

5.4 Quality studies

5.4.1 Crude protein content

Irrigation increased the crude protein content of the fodder which can be attributed to the increased uptake of nitrogen under irrigated condition (Malkov *et al.*, 1978). FYM and fertilizers had little effect on the crude protein content upto 7.5 t ha^{-1} of FYM and 150 : 50 : 50 kg ha^{-1} of NPK. P and K fertilizers were reported to reduce the crude protein content of fodder (Bahl *et al.*, 1970 and Andrade *et al.*, 1996). Contrary to this finding, Thakuria (1993) reported an increase in crude protein content by phosphorus and potash applications to soil.

5.4.2 Crude fibre content

Crude fibre content of the fodder remained almost unaltered by the imposition of various treatments viz., irrigation, FYM application and fertilizer application. This indicated that FYM @ 7.5 t ha^{-1} and NPK @ 150 : 50 : 50 kg ha^{-1} were insufficient to produce any significant change in the crude fibre content of fodder under irrigated condition.

5.4.3 K : (Ca + Mg) ratio

K : (Ca + Mg) ratio was found to be high in medium irrigated and rainfed plots. The variation in K : (Ca + Mg) value was very less among the treatments. Hence, no treatment can be pointed out to be having significantly high or low K : (Ca + Mg) ratio. In all the cases the ratio was quite below the safe limit of 2.2.

The effect of various treatments on the quality aspects of fodder is shown in Fig. 5.4.1.1.

5.5 Soil moisture studies

5.5.1 Field water use efficiency

Field water use efficiency was found to be more in the rainfed treatment than in the irrigation treatments. It is contrary to the general trend of increased water use efficiency of crops under irrigated conditions. The increased water use efficiency of rainfed crop was mainly due to a few unoccassional heavy rains (clear from the weather data - Appendix - I and Fig. 3.1) received during the crop period; which contributed much to the soil moisture status.

5.5.2 Soil moisture depletion pattern

Generally the moisture depletion from top 0-30 cm layer of soil was more in irrigated plots than in rainfed plots. In rainfed crop, roots extracted moisture from deeper layers of soil than from the dry surface layer. Enough water was available on the top layer of soil under irrigated conditions. Hence, roots tended to concentrate on the surface layer of soil and depleted more water from there. High dose of fertilizer was found to enhance moisture depletion from the top layer of soil. Fertilizers were applied on the soil surface and for their proper uptake water was necessary. Because of this, when more fertilizers were applied, more water was depleted from the surface layer of soil.

Moisture depletions from 30-60 and 60-90 cm depths were maximum in rainfed and least in irrigated plots. FYM application and lower level fertilizers were also found to increase the moisture depletion from deeper layers of soil.

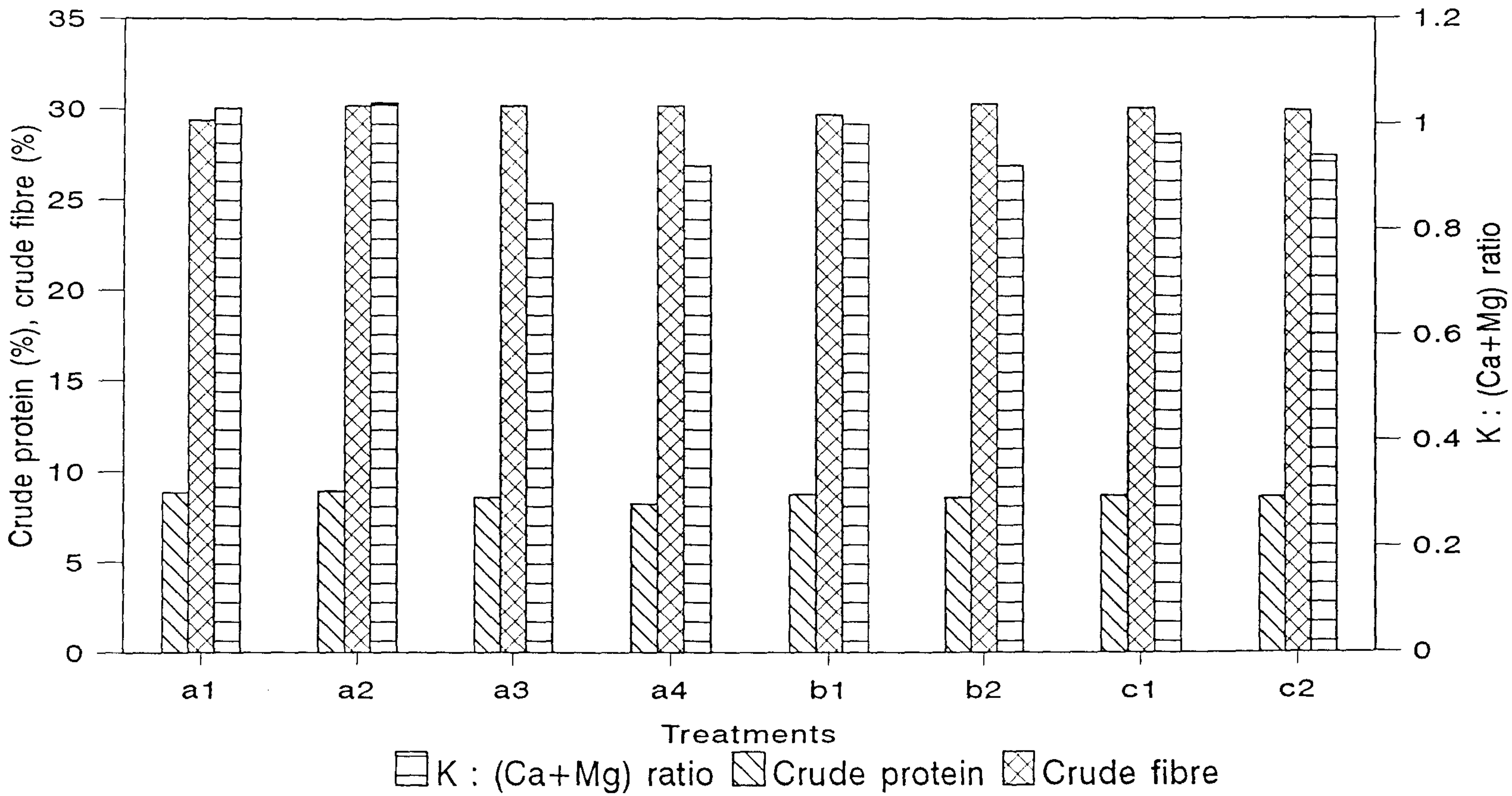


Fig. 5.4.1.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on K : (Ca + Mg) ratio, crude protein content and crude fibre content of congosignal on dry weight basis

5.6 Root studies

5.6.1 Root length

Irrigation had a positive influence on the root length of congosignal. Even though the roots had more length under irrigated conditions, they remained as an entangled mass on the surface layer of soil. Roots were shortest in the rainfed treatment. In rainfed plots, lateral spread of roots was limited; instead, roots grew almost vertically downwards. Along with irrigation, FYM application resulted in an increase in root length, but in rainfed plots a reduction in root length with FYM application was noticed. The difference in root growth by various irrigation treatments is shown in plate 7.

5.6.2 Root weight

The mean root weight per plant was higher in irrigated treatments than in rainfed treatment. This was resulted from the enhanced root growth of the grass under irrigated condition. FYM and fertilizer application @ 7.5 t ha^{-1} and 150 : 50 : 50 kg NPK ha^{-1} respectively did not result in a significant increase in the root weight of congosignal.

5.7 Economics of cultivation

5.7.1 Net income

Medium irrigation treatment (irrigation at 45 mm CPE) gave the highest net income. In the highest irrigation treatment, net income was lower due to higher cost of irrigation. Hence, it can be concluded that on net income basis, the second level of irrigation (irrigation at 45 mm CPE) was the best as it is clear from

Plate 7 Comparison of root growth of Congosignal under various irrigation levels

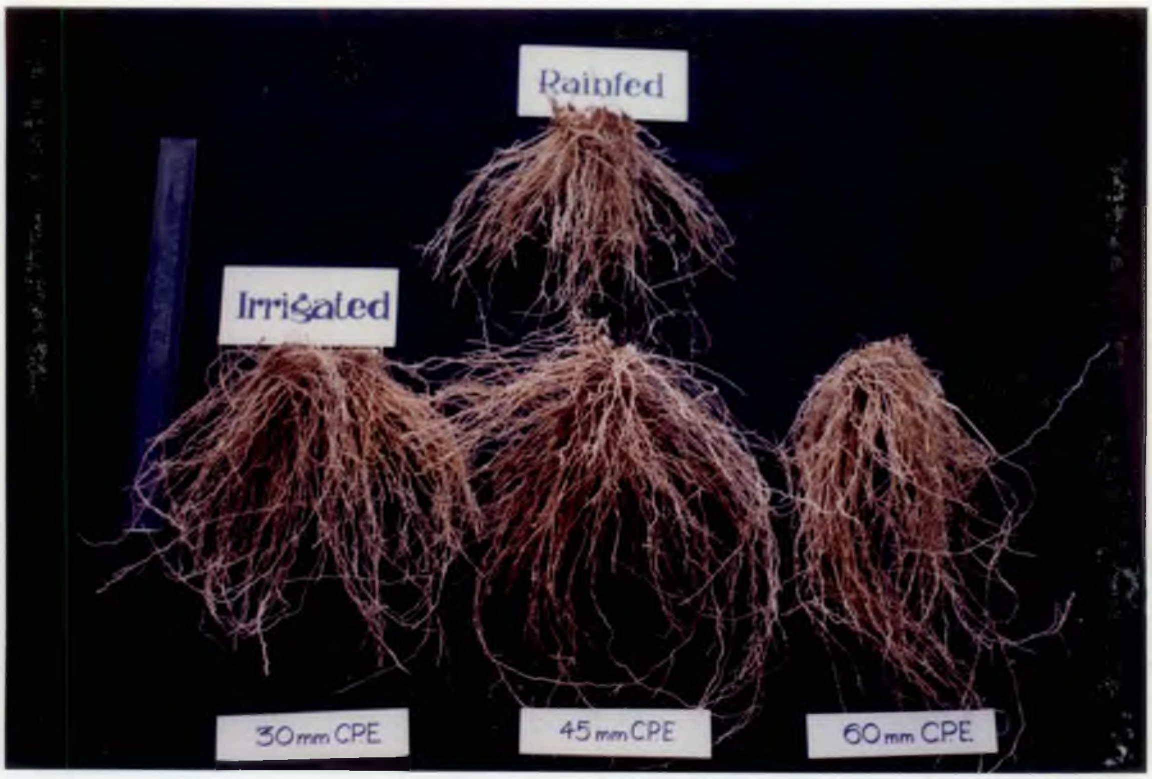

Rainfed
Irrigated
30 mm CPE
45 mm CPE
60 mm CPE

Fig. 5.7.1.1. The net income in all other treatments did not vary significantly. The lowest net income was recorded in the highest irrigation treatment.

5.7.2 Benefit : cost ratio

As in the case of net income, benefit : cost ratio was also high in 45 mm CPE irrigation treatment (Fig. 5.7.1.1). There was no significant difference among the benefit : cost ratios of other irrigated and rainfed treatments. The lowest benefit : costratio was recorded in the highest irigation treatment which may be due to the higher cost incurred for irrigation. Considering the combination of various treatments, the most economic treatment combination was irrigation at 45 mm CPE, FYM @ 5.0 t ha^{-1} and NPK @ 150 : 50 : 50 kg ha^{-1}.

5.8 Yield of coconuts

Coconut palms in the experimental site were having relatively poor yields during the pre-experimental period. The annual nut production per palm was in the range 27-43 nuts y^{-1}, two years before the experiment. This was improved to 34 - 46 nuts $palm^{-1}$ y^{-1} during the crop period. The result was in accordance with the reports of Pillai (1986) and George (1996). The increased nut yield $palm^{-1}$ can be attributed mainly to the reduction in button shedding, which was a favourable effect of grass intercropping.

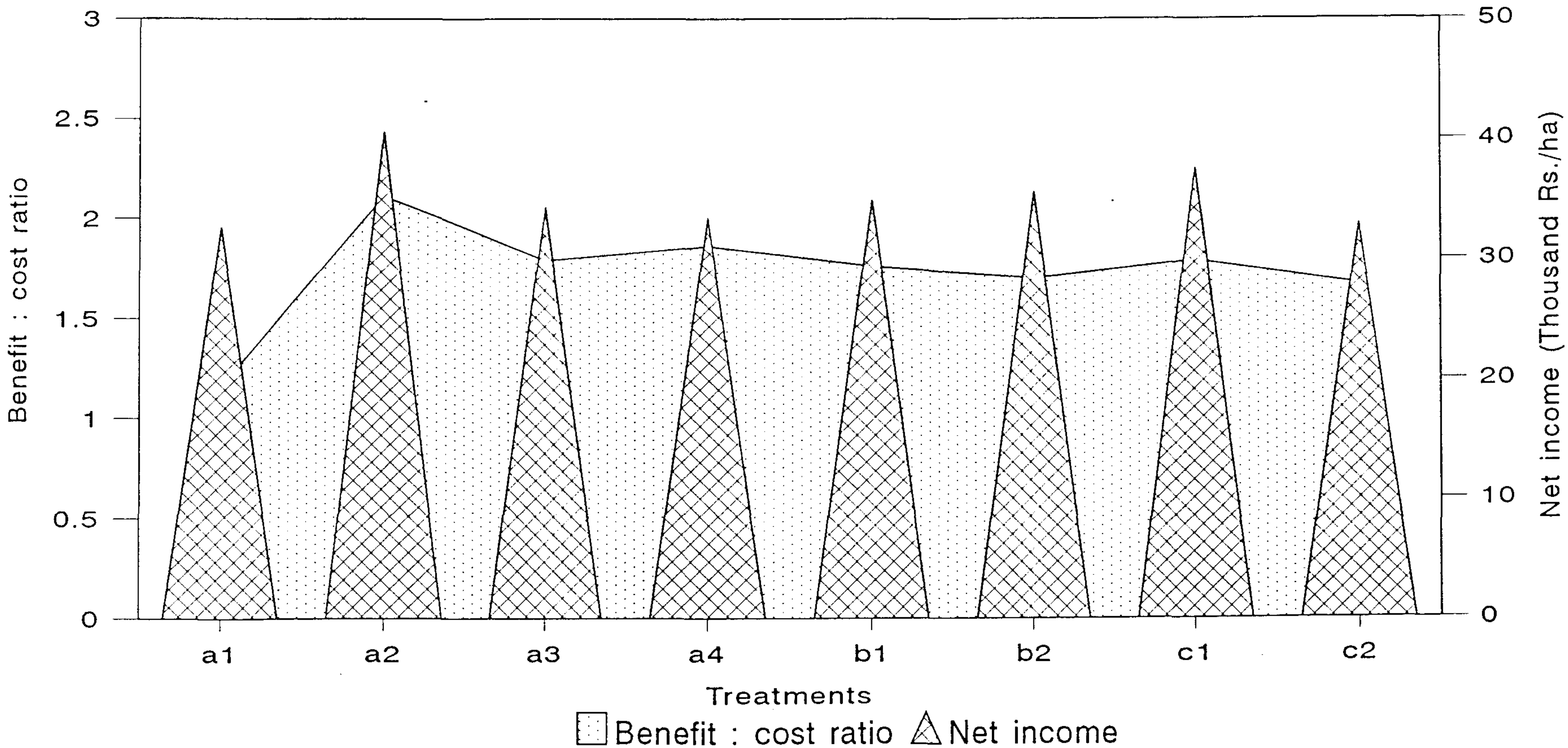


Fig. 5.7.1.1. Effect of irrigation (a), FYM (b) and fertilizers (c) on net income and benefit : cost ratio of congosignal cultivation

SUMMARY

6. SUMMARY

This investigation entitled **Intensive fodder production under irrigated condition in partial shade** was conducted in the upland coconut gardens of Instructional Farm of College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, for a period of one year from July 1998 to June 1999.

The response of congosignal grass (*Brachiaria ruziziensis* Germain and Evrardi) grown in partially shaded coconut garden, to various levels of irrigation, farm yard manure and fertilizers were studied. The changes in physico-chemical properties of soil due to fodder grass cultivation was also investigated. The economics of irrigated fodder production under partially shaded condition was worked out.

The experiment consisted of three levels of irrigation viz., irrigation at 30 mm, 45 mm and 60 mm CPE, a rainfed control, two levels of organic manure (5.0 and 7.5 t ha^{-1}) and two levels of nutrients viz., 100 and 50 per cent of package of practices recommendations of Kerala Agricultural University. There was altogether 16 treatment combinations. The experiment was laid out in factorial Randomised Block Design with three replications.

The salient findings of the experiment are summarised below :

1. Irrigation at 30 and 45 mm CPE, FYM application @ 7.5 t ha^{1} and NPK @ 150 - 50 - 50 kg ha^{-1} increased the plant height of congosignal.

2. In combination with irrigation, both levels of FYM (5.0 and 7.5 t ha^{-1}) enhanced the plant height.
3. AT 30 mm CPE irrigation, 50 per cent of the recommended dose of fertilizers was sufficient for optimum plant growth.
4. Irrigation at 30 mm CPE and application of 7.5 t ha^{-1} FYM and 150 - 50 - 50 kg NPK ha^{-1} increased the tiller production in congosignal.
5. The level of FYM @ 7.5 t ha^{-1} together with irrigation produced higher number of tillers.
6. Under rainfed condition, the number of tillers produced with 7.5 and 5.0 t ha^{-1} of FYM were on par.
7. Leaf : stem ratio of congosignal grass increased with irrigation levels.
8. There was no significant difference between the lower and higher levels of FYM (5.0 and 7.5 t ha^{1}) with regard to the leaf : stem ratio.
9. 100 per cent of the recommended dose of fertilizers (NPK @ 150 - 50 - 50 kg ha^{-1}) increased the leaf : stem ratio.
10. Leaf area index showed a positive correlation with irrigation upto 45 mm CPE irrigation, above which the increase was not significant.
11. Increased doses of FYM and fertilizers increased the leaf area index.
12. A variability in different interaction effects of treatments on growth parameters was observed due to sudden changes in the climatic parameters during the crop period.
13. Irrigation at 30 mm CPE and NPK @ 150 : 50 : 50 kg ha^{-1} increased the green fodder yield of congosignal.

14. FYM alone had no positive effect on green fodder yield. But significant yield increase was noticed when 7.5 t ha^{-1} of FYM was applied along with 30 mm CPE irrigation.

15. As in the case of green fodder yield, dry fodder yield was also directly related to irrigation and fertilizer levels. FYM application up to 7.5 t ha^{-1} did not produce any significant effect on the dry fodder yield of congosignal.

16. Irrigation at 30 mm CPE increased the N, P, K, Ca and Mg uptake in congosignal.

17. FYM application up to 7.5 t ha^{-1} recorded no appreciable increase in the uptake of nutrients.

18. NPK dose @ 150 : 50 : 50 kg ha^{-1} increased the uptake of nutrients by congosignal grass.

19. Interaction effect of 30 mm CPE irrigation and application of FYM and chemical fertilizers increased the nitrogen uptake.

20. Grass cultivation reduced the bulk density of coconut garden soils. Higher levels of irrigation and fertilizers had a beneficial effect on the bulk density. But, FYM application at 5.0 or 7.5 t ha^{-1} did not improve the bulk density significantly.

21. Interaction effect of irrigation and FYM @ 7.5 t ha^{-1} significantly reduced the soil bulk density.

22. Irrigation at 30 mm CPE and application of fertilizers and FYM increased the water holding capacity and porosity of soil.

23. Interaction effect of the combination of high irrigation levels (30 and 45 mm CPE) and 7.5 t ha^{-1} of FYM was significant in improving the water holding capacity of soil.

24. Irrigation and FYM application increased the organic carbon content of soil
25. Available nitrogen status of soil remained almost unchanged by irrigation, FYM and fertilizer treatments.
26. Available phosphorus and potassium status of the soil was increased by irrigation, while FYM and fertilizer applications had no significant effect on P and K availability.
27. Irrigation increased the crude protein content of the fodder. The quality aspects like crude fibre content and K : (Ca + Mg) ratio remained unaffected by the treatments.
28. Irrigation at 30 and 45 mm CPE and application of 150 - 50 - 50 kg NPK ha^{-1} increased the water depletion from 0 - 30 cm layer of soil.
29. Root growth (root length and root weight) of congosignal was favoured by irrigation.
30. Under partially shaded conditions, irrigation at 45 mm CPE gave maximum net income and benefit : costratio when compared to 30 mm CPE and 60 mm CPE irrigation levels and the rainfed treatment.
31. The physical optimum levels of inputs were irrigation at 30 mm CPE, FYM @ 7.5 t ha^{-1} and NPK @ 150 : 50 : 50 kg ha^{-1} and the economic optimum levels were irrigation of 45 mm CPE, for congosignal production in coconut gardens.

Future line of work

The results of the present investigation point towards a better scope for intensive fodder production in coconut gardens. High yielding good quality fodder crops with good tolerance to shade and adaptability to different agroclimatic zones of Kerala need to be identified and popularised among dairy farmer's fields. The levels of irrigation, FYM and fertilizers for producing optimum fodder yields under shaded condition is to be standardised for different fodder species. In the present study, recommended doses of manures and fertilizers were found to be giving highest benefit : cost ratio for congosignal grown under irrigated condition in partial shade. Hence, further investigations can be undertaken to find out whether lower doses of manures and fertilizers are sufficient under rainfed condition when the grass is grown as an intercrop. Studies can also be conducted to test whether the irrigation given for the base crop is sufficient for the intercrop. Permanent manurial trials may be conducted to investigate upon the residual effects of manures and fertilizers on the base crop and intercrop under continuous fodder intercropping system. The extent to which the costly chemical fertilizers can be substituted by cheap and locally available organic sources of nutrients for fodder cultivation also needs immediate attention of forage scientists.

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* Originals not seen

APPENDIX

APPENDIX - I

Weather data for the crop period - Weekly averages (July 1998 - June 1999)

Period	Max. temp. (^0C)	Min. temp. (^0C)	Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
1998					
July 1 - July 7	30.30	23.63	80.21	0.029	1.81
July 8 - July 14	30.39	28.41	82.79	2.77	6.80
July 15 - July 21	28.83	23.89	85.79	4.00	2.71
July 22 - July 28	29.19	23.91	86.07	1.57	3.46
July 29 - Aug. 4	29.59	24.84	85.71	0.70	3.13
Aug. 5 - Aug. 11	30.07	24.24	83.00	2.77	3.56
Aug. 12 - Aug.18	30.74	24.83	81.93	0.31	3.80
Aug. 19 - Aug. 25	29.01	26.80	87.50	16.74	2.21
Aug. 26 - Sep. 1	30.19	24.17	82.29	0.04	3.59
Sep. 2 - Sep. 8	29.96	24.13	83.14	8.69	3.80
Sep. 9 - Sep. 15	29.75	23.97	85.29	13.46	3.06
Sep. 16 - Sep. 22	25.97	24.03	88.21	7.54	3.73
Sep. 23 - Sep. 29	28.71	23.50	84.93	15.00	2.61
Sep. 30 - Oct. 6	29.60	24.16	86.57	0.94	2.96
Oct. 7 - Oct. 13	28.24	23.21	94.29	51.91	1.94
Oct. 14 - Oct. 20	30.20	23.70	83.50	5.69	3.60
Oct. 21 - Oct. 27	30.54	23.70	81.64	-	4.01
Oct. 28 - Nov. 3	30.07	23.04	81.86	2.54	2.86
Nov. 4 - Nov. 10	28.77	23.39	89.14	41.57	2.20
Nov. 11 - Nov. 17	30.07	23.10	82.71	7.43	3.30
Nov. 18 - Nov. 24	30.57	23.07	78.36	-	3.57
Nov. 25 - Dec. 1	30.74	23.76	84.36	1.51	2.94
Dec. 2 - Dec. 8	30.9	23.43	83.07	16.77	2.60
Dec. 9 - Dec. 15	29.20	23.11	87.09	5.54	1.90
Dec. 16 - Dec. 22	30.79	23.08	85.00	6.86	2.87

Appendix - I Contd...

Period	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
Dec. 23 - Dec. 29	31.34	21.14	85.50	0.86	2.79
Dec. 30 - Jan. 5 1999	30.93	22.63	92.93	0.46	2.11
Jan. 6 - Jan 12	31.49	22.27	94.71	-	6.14
Jan. 13 - Jan 19	31.34	22.53	92.50	-	3.59
Jan. 20 - Jan 26	31.36	21.27	77.43	-	2.27
Jan. 27 - Feb. 2	30.63	21.37	76.29	0.29	3.53
Feb. 3 - Feb. 9	30.94	22.27	83.00	11.23	3.97
Feb. 10 - Feb. 16	31.40	23.06	81.64	-	3.77
Feb. 17 - Feb. 23	31.80	23.14	84.39	-	3.77
Feb. 24 - Mar. 2	31.93	23.11	80.00	-	3.96
Mar. 3 - Mar. 9	32.20	23.09	78.79	-	4.31
Mar. 10 - Mar. 16	32.70	24.31	80.71	0.26	4.34
Mar. 17 - Mar. 23	32.53	25.23	81.21	7.74	4.51
Mar. 24 - Mar. 30	32.73	25.34	82.00	0.31	4.03
Mar. 31 - Apr. 6	32.44	24.90	80.71	-	4.23
Apr. 7 - Apr. 13	32.30	25.06	81.14	4.15	4.44
Apr. 14 - Apr. 20	32.04	25.41	82.57	0.14	4.06
Apr. 21 - Apr. 27	29.1	24.00	87.64	15.83	2.73
Apr. 28 - May 4	31.69	25.51	87.64	0.89	4.03
May 5 - May 11	30.97	24.40	83.07	6.11	2.99
May 12 - May 18	31.03	24.00	85.43	21.14	2.93
May 19 - May 25	29.54	23.16	88.07	15.91	2.61
May 26 - June 1	29.43	23.69	88.57	15.41	2.71
June 2 - June 8	28.01	23.51	89.71	36.63	2.47
June 9 - June 15	28.21	23.09	91.43	14.77	1.74
June 16 - June 22	30.24	24.79	82.86	5.14	3.49
June 23 - June 29	31.10	24.17	78.79	-	3.94

INTENSIVE FODDER PRODUCTION UNDER IRRIGATED CONDITION IN PARTIAL SHADE

By

ROMY JACOB

ABSTRACT OF THESIS
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ABSTRACT

A field experiment was conducted in the upland coconut gardens of Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, to study the potential of intensive fodder cultivation under shaded condition. The influence of irrigation, FYM and fertilizers on the yield and quality of fodder and the effect of grass cultivation on the physico-chemical properties of soil were studied. The economics of irrigated fodder production was also worked out. The investigation was conducted for a period of one year from July 1998 to June 1999.

The results revealed that irrigation at 30 and 45 mm CPE improved the growth parameters like plant height, tiller number hill^{-1}, Leaf : Stem ratio and Leaf Area Index of congosignal and gave higher green fodder as well as dry fodder yields. Application of 7.5 t ha^{-1} of FYM increased the plant height, tiller number hill^{-1} and Leaf Area Index. The uptake of plant nutrients viz., N, P, K, Ca and Mg by congosignal was favoured by irrigation. Application of FYM was not found to enhance the nutrient uptake, but, chemical fertilizers improved the uptake of nutrients by congosignal.

Soil physical properties like bulk density, water holding capacity and porosity were improved by grass cultivation. Irrigation and application of FYM and fertilizers improved the soil physical properties. Irrigation and FYM application increased the soil organic carbon content. Available P and K status of the soil was improved by irrigation, while available N status remained

almost unchanged. FYM or fertilizer application did not change the available N, P and K content of soil upto 7.5 t ha^{-1} of FYM and 150 : 50 : 50 kg NPK ha^{-1}.

Irrigation improved the fodder quality in terms of crude protein content. There was no improvement in the quality of fodder by FYM or fertilizer application at the recommended doses. Irrigated congosignal crop depleted more moisture from the top 0 - 30 cm layer of soil. The rainfed crop extracted more water from deeper layers than the irrigated crop. Root growth of congosignal was favoured by irrigation. While considering the economics of fodder cultivation, 45 mm CPE irrigation treatment was found to be the best, when compared to treatments involving 30 and 60 mm CPE irrigation and the rainfed control. Highest benefit : cost ratio was recorded for the treatment combination : irrigation at 45 mm CPE and recommended doses of manures and fertilizers (FYM @ 5.0 t ha^{-1} and NPK @ 150 : 50 : 50 kg ha^{-1}) when congosignal was grown as an intercrop in coconut garden.