EVALUATION AND NUTRITIONAL MANAGEMENT OF FODDER CROPS IN SUMMER RICE FALLOWS

By

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THESIS
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DECLARATION

I hereby declare that this thesis entitled **"Evaluation and nutritional management of fodder crops in summer rice fallows"** 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.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"Evaluation and nutritional management of fodder crops in summer rice fallows"** is a record of research work done independently by Ms. Salini Rani. V. G. (98-11-04) 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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Dedicated to my dearest daughter Aiswarya

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Salini Rani. V. G.

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LIST OF ABBREVIATION

@	– at the rate of
CEC	– Cation Exchange Capacity
CD	– Critical difference
cm	– centimetre
CF	– Chemical fertilizer
^{0}C	– Degree Celsius
CSRC	– Cropping Systems Research Centre
DAS	– Days after sowing
EC	– Electrical conductivity
et al.	– and others
FYM	– Farmyard manure
Fig	– Figure
ha	– hectare
K	– Potassium
kg	– Kilogram
LAI	– Leaf area index
mm	– Millimeter

MSL	– Mean sea level
N	– Nitrogen
P	– Phosphorus
POP	– Package of practices
q	– quintal
t	– tonnes
VC	– Vermicompost
WHC	– Water holding capacity

INTRODUCTION

1. INTRODUCTION

India is basically an agricultural country and about 70 per cent of the population live in villages. Their livelihood is depended mainly on agriculture and animal husbandry. Dairy farming is an important component of mixed farming system which has sustained Indian agriculture since ages by providing strong economical support to the farmers.

India is blessed with a tremendous live stock wealth and is endowed with a significant share of the world's live stock population. Though the country possess one fifth of the world's bovine population it contributes only around 8 per cent of the world's milk production. This is mainly due to the low productivity of animals. The shortage of adequate quantity of quality forage is one of the important factors responsible for the low production of milk. A regular supply of green fodder is extremely important as it is rich in minerals and other nutrients required for the dairy animals. It improves the quantity and quality of milk and helps the animals to express their full genetic potential. It is rightly stated that " no fodder, no cattle; no cattle, no manure: no manure, no crop". It is well documented that feed cost contributes to about 70 per cent of the total cost of dairy farming. By including sufficient quantity of green fodder in animal diet the cost of feeding can be reduced to 50 per cent.

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. Summer rice fallows offer a good opportunity for fodder production in Kerala where land available for fodder cultivation is limited. Cultivation of quick growing and short duration fodder crops in the summer rice fallows will provide valuable green fodder during the peak period of its demand within a stipulated time.

Cereal fodders have low protein content but it is relished by the animals, being succulent and palatable. Bajra and sorghum are important sources of cattle feed and fodder. They are quick growing, short duration, drought tolerant fodder crops having better nutritive value, high forage yield and acceptability by animals. Legume fodders are valued for their nutritive quality especially by virtue of their high crude protein and calcium content in addition to the green fodder yield. Among them, cowpea is a quick growing crop which provides fodder especially during summer season when there is scarcity of green fodder. C-152 is a cowpea variety known for its fodder production potential under rainfed conditions. *Sesbania rostrata* is a promising legume to be tried as a fodder crop owing to its high biomass production and nutrient contents.

Fertilizers play an important role in increasing production of fodder with better nutritive value. Since fertilizer alone accounts for more than 40 per cent of the cost of production of forage crops it is very much necessary to find ways to economise fertilization without reduction in the productivity of forage crops. Fertilizer nutrients are costly inputs and they pose problems on soil health and pollution on a long run. Therefore during the recent past, our agriculture urged the use of organic sources of nutrients (Gowda and Babu, 1999). Here comes the importance of integrated plant nutrient management (IPNM) which is ecologically sound, economically viable and socially just. There is increasing awareness about sustainable agriculture system world wide in a view of energy shortages, food safety and soil and environment pollution arising out of chemical farming. It is possible to effect a quick change over to sustainable agriculture by harnessing vermicompost biotechnology in soil (Bhawalkar and Bhawalkar, 1992). Among the different available organic manures, vermicompost is a potential source due to the presence of readily available plant nutrients, growth enhancing substances and a number of beneficial microorganisms like nitrogen fixing, phosphorus solubilising and cellulose decomposing organisms. Vermicompost can substitute or complement chemical fertilizers. It contains various amino acids and minerals which humidify the organic matter in the surrounding soil and acts as a biofertilizer for plants (Shanbhag, 1999). A higher proportion of organic sources of nutrients, as a renewable source and supplement to chemical fertilizer is considered environment friendly in terms of protecting the quality of underground water, soil property and the environment in general (Motsara, 2000).

Keeping these views under consideration the present investigation entitled "Evaluation and nutritional management of fodder crops in summer rice fallows" was carried out at Cropping Systems Research Centre (CSRC), Karamana, Thiruvananthapuram with the following objectives.

★ To evaluate the production potential and quality of different fodder crops in summer rice fallows under different nutrient levels.

★ To study the changes in physico-chemical properties of soil due to fodder cropping and

★ To work out the economics of fodder production.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Intensive fodder production in summer rice fallows is one of the important ways to increase the fodder production of the state. In order to get high tonnage and good quality fodder, adoption of suitable agronomic practices and introduction of nutritious and short duration drought tolerant cereal and leguminous fodder crops in summer rice fallows will help in mitigating the crisis of fodder scarcity. Chemical fertilizers are costly inputs and their use pose problems on soil health and pollution on a long run. Combination of organic matter and chemical fertilizers play a key role in modern agriculture for increasing the productivity of crop and the sustained management of soil fertility.

The present investigation was carried out at Cropping Systems Research Centre (CSRC), Karamana during the period from February – May 2000 to evaluate the production potential and quality of different fodder crops in summer rice fallows under different nutrient levels and to study the changes in physico-chemical properties of soil due to fodder cropping. The literature pertaining to the above subject are reviewed here under. Wherever sufficient literature in not available on the crops tried in this experiment, results of similar experiments conducted on related crops are also cited.

2.1 Effect of chemical fertilizers on growth, yield and quality of fodder crops

2.1.1 Growth characters

2.1.1.1 Plant height

Abdel – Raouf *et al.* (1967) observed a significant increase in height of sudan grass (*Sorghum sudanens*) with the application of higher doses of nitrogen fertilizer. Boonman (1972) noticed a pronounced increase in length of stem of setaria grass (*Setaria sphacelata*) cv. Nandi by nitrogen application. A considerable increase in the height of plants was observed by Singh *et al.* (1973) by the application of nitrogen to oats (*Avena sativa*). Rathore and Vijayakumar (1977) reported the influence of nitrogen in increasing plant height in fodder sorghum (*Sorghum bicolor*). Abraham (1978) noticed a linear increase in plant height in dinanath grass (*Pennisetum pedicellatum*) with increase in nitrogen application. A linear increment in height of sorghum with higher levels of nitrogen at 30^{th} and 60^{th} days after sowing was reported by Shanjeevirayar (1978). Thomas (1978) observed a significant increase in height with nitrogen doses upto 250 kg ha^{-1} in hybrid napier.

Taller plants were recorded in sorghum applied with 120 kg N ha^{-1} (Singh and Singh, 1983). A marked increase in the height of sorghum upto 40 kg N ha^{-1} was noticed by Balyan and Singh (1985). Devasenapathy and Subbarayalu (1985) reported significant increase in plant height of grain sorghum fertilized upto 90 kg N ha^{-1}. Kothari and Saraf (1987) reported that plant height of fodder sorghum increased significantly with the application of nitrogen. Munegowda *et al.* (1987) observed increase in plant height of hybrid napier with increase in fertility levels.

Patel and Parmar (1987) reported that in pearl millet the growth attributes such as plant height increased with nitrogen application only upto 80 kg ha^{-1}. According to Shivanand *et al.* (1987) height and girth of shoot increased with successive increase in fertilizer level from 50:30:20 to 150:90:60 kg NPK ha^{-1} in fodder sorghum. In fodder pearl millet the plant height increased significantly with increasing levels of nitrogen from 30 to 90 kg ha^{-1} (Manohar *et al.*, 1992).

Shanti *et al.* (1997) found that plant height of maize was maximum when 160 kg N ha^{-1} was applied. Barik *et al.* (1998) observed that plant height increased significantly at different stages of growth of sorghum with the increase in the level of nitrogen. Singh *et al.* (1998) reported that plant height and number of shoots increased with increasing levels of nitrogen in forage oats. In signal grass application of 200 kg N ha^{-1} recorded the maximum plant height (Sonia, 1999).

Jayakumar (1997) noticed increased height and spread of legume inter crops in hybrid napier due to the application of inorganic nitrogen. Khanda (1999) observed that increasing nitrogen rates from 0 to 40 kg ha^{-1} increased the plant height from 51.22 to 69.83cm in winter rice bean.

Pande (1972) in an experiment with green gram observed an increase in plant height with increasing levels of phosphorus. Maharana and Das (1973) observed that the effect of phosphorus was not significant in increasing the plant height in cowpea. Chandini (1980) showed that application of phosphorus increased the height and tiller number of fodder grasses and spread of legumes. Geethakumari (1981) reported that in fodder cowpea, plant height significantly increased with increasing levels of phosphorus and at flowering stage, application of 50 kg P_2O_5 ha^{-1} recorded the maximum plant height. Singh (1985) observed an increase in plant height in summer cowpea at a higher level of phosphorus (60 kg P_2O_5 ha^{-1}) compared to lower levels of phosphorus (20 and 40 kg P_2O_5 ha^{-1}). Murali (1989) observed that a maximum plant height of 135.56 cm was obtained with the application of 30 kg P_2O_5 ha^{-1} in *Sesbania rostrata*. Thakuria and Luikham (1991) reported that in folder cowpea, phosphorus application at 50 kg P_2O_5 ha^{-1} influenced the plant height over other levels. Rajasree (1994) observed that taller plants were produced when 60 kg P_2O_5 ha^{-1} was applied to cowpea and

Sesbania rostrata. Mishra and Baboo (1999) reported that application of P at 90 kg P_2O_5 ha^{-1} recorded significantly higher plant height than 30 and 60 kg P_2O_5 in cowpea.

Application of 40 kg K_2O ha^{-1} significantly influenced the plant height of black gram at 45 DAS and at harvest. (Shah *et al.*, 1994). Sonia (1999) found that application of potassium at 150 kg ha^{-1} significantly increased the plant height of Signal grass at forth harvest.

2.1.1.2 Leaf Area Index

In cowpea application of nitrogen was ineffective in increasing the leaf number, growth and LAI (Dhanram *et al.*, 1971). Das and Chatterjee (1976) observed that in dinanath grass 95 per cent light interception occurred at a LAI of 7.5. Evans and Wardlaw (1976) proved that maximum light interception in cereals occurred at LAI of four and further increase in LAI had little effect on photosynthesis.

Nitrogen application increased the number of leaves per plant and leaf area at 30^{th} and 60^{th} days in sorghum (Shanjeevirayar, 1978). Kothari and Saraf (1987) reported that green leaves per plant of fodder sorghum increased with increasing levels of nitrogen. Malik *et al.* (1992) observed a pronounced positive effect of nitrogen on leaf number in fodder sorghum. Manohar *et al.* (1992) obtained a significant increase in leaves per plant with an increase in nitrogen from 30 to 90 kg ha^{-1} in fodder pearl millet. Jena *et al.* (1995) found that LAI of fodder cowpea was maximum when 40 kg N ha^{-1} was applied. Application of 160 kg N ha^{-1} recorded the highest LAI of 1.72 in maize compared to other treatments (Shanti *et al.*, 1997). Barik *et al.* (1998) concluded that LAI increased significantly with increasing levels of nitrogen in sorghum. Ayub *et al.* (2000) found that all rates of nitrogen gave significantly higher leaf area per plant over control in maize and leaf area with 100 kg N ha^{-1} was statistically similar to that recorded with 150 kg N ha^{-1}.

Tarila and Ormod (1977) reported that increasing levels of phosphorus increased the leaf area index in cowpea. Geethakumari (1981) observed a linear increase in leaf area index with increased application of phosphorus during early stages of growth in cowpea. LAI showed a clear trend of increase with increase in the rates of P applied in cowpea (Balakumaran, 1981). In an experiment with *Sesbania rostrata* Halepyati and Sheelavantar (1989) reported that application of phosphorus increased the supply of nitrogen for the biological activity of the plant resulting in higher leaf area. Baboo and Mishra (2001) reported that in cowpea every increase in P rates from 0 to 90 kg ha^{-1} increased the number of green leaves, dry matter accumulation and nodules per plant.

Munegowda *et al.* (1987) observed that the number of leaves and nodes of hybrid napier var. NB-21 grass increased with increase in fertility levels upto 180:120:80 kg NPK ha^{-1}. Shivanand *et al.* (1987) reported that number of green leaves increased with successive increase in fertility levels from 50:30:20 to 150:90:60 kg NPK ha^{-1} in fodder sorghum.

2.1.1.3 Leaf : Stem Ratio

Singh *et al.* (1973) reported a gradual decrease in L:S ratio with increase in the N level L:S ratio decreased significantly from 2.0 to 1.7 at 120 kg N ha^{-1} in forage oats. A significant decrease in L:S ratio in dinanath grass and forage Sorghum with the addition on nitrogen was reported by Rathore and Vijayakumar (1977). Thomas (1978) observed a significant reduction in L:S ratio with higher dose of 200 and 250 kg N ha^{-1}. Kothari and Saraf (1987) reported an increase in L:S ratio and moisture content with increased application of nitrogen. Yeh (1988) noticed that nitrogen application had not much effect on L:S ratio of hybrid napier. A negative correlation between L:S ratio and drymatter yield was observed by Williams and Hanna (1995). Jayakumar (1997) noted a decrease in L:S ratio in hybrid Napier grass and an increase in L:S ratio in legumes with the application of nitrogen. Singh *et al.*

(1998) reported that number of shoots and L:S ratio increased with increasing levels of nitrogen in forage oats.

Mariyappan (1978) indicated an increasing trend in L:S ratio with increased levels of phosphorus upto 120 kg ha^{-1} in *Stylosanthes gracilis*. Pillai (1986) showed that application of phosphorus significantly increased the leaf:stem ratio of *Stylosanthes guinensis* both in open and shaded conditions.

Combined application of moderate levels of nitrogen and phosphorus recorded maximum leafiness in Stylosanthes (De Gesus, 1977). Shivanand *et al.* (1987) reported that L:S ratio and drymatter accumulation into leaf and stem increased with successive increase in fertility levels from 50:30:20 to 150:90:60 kg NPK ha^{-1} in fodder sorghum. Sonia (1999) noticed that there was no marked difference between lower and higher levels of nitrogen and potassium with regard to L:S ratio.

2.1.2 Yield

2.1.2.1 Green fodder yield

Boruah and Mathur (1979) reported a significant increase in green fodder yield by nitrogen application in fodder oats. Green fodder yield response to nitrogen application was reported in pearl millet by Katoria *et al.* (1981) and in sorghum by Singh and Singh (1983). Kaushik and Gautam (1987) studied the response of pearl millet genotypes to nitrogen under dry land condition and opined that fodder yield increased linearly as the nitrogen levels were increased from 0 to 90 kg ha^{-1}. According to Kothari and Saraf (1987) optimum doses of nitrogen for fodder sorghum was 86.4 kg N ha^{-1}which gave a response of 1.23 q ha^{-1} of green fodder per kg nitrogen. In pearl millet the fodder yield increased significantly with increasing levels of nitrogen upto 160 kg ha^{-1} (Patel and Parmar, 1987) Hunshal *et al.* (1989) noticed that 200 kg N ha^{-1} increased the green fodder yield of South American maize significantly over 50 kg N ha^{-1}. Thaware *et al.* (1991) reported that application of 200 kg N ha^{-1} significantly increased the yield over 100 kg N ha^{-1} in forage maize. Malik *et al.* (1992) observed a significant increase in green fodder yield by increased nitrogen levels upto 120 kg N ha^{-1} in fodder sorghum. An increased application of nitrogen from 30 to 120 kg ha^{-1} increased the green fodder yield in fodder sorghum (Shukla and Sharma, 1994). Singh *et al.* (1994) and Meena *et al.* (1998) reported that grain and fodder yields increased significantly with moderate doses of nitrogenous fertilizers in pearl millet. Maximum green fodder yield in fodder maize was obtained when supplemented with 90 kg N ha^{-1} (Ghosh and Singh, 1996).

Under rainfed conditions Gautum and Kaushik (1997) observed that the fodder yield increased linearly upto 60 kg N ha^{-1} in pearl millet. Barik *et al.* (1998) revealed that the application of 120 kg N ha^{-1} resulted in higher green forage yields of sorghum compared to lower doses. Krishna *et al.* (1998) observed maximum green fodder yield in fodder maize supplemented with 180 kg N ha^{-1}. Thakur *et al.* (1998) reported a significant increase in green fodder yield with increase in nitrogen application from 0 to 200 kg ha^{-1}. Stover yield and harvest index (per cent) increased with increase in nitrogen levels from 75, 150 and 225 kg ha^{-1} in spring maize (Tyagi *et al.*, 1998). Sonia (1999) observed a pronounced increase in green fodder yield of signal grass by increasing application of nitrogen and the maximum green fodder yield was produced by the highest dose of nitrogen (200 kg N ha^{-1}).

In an experiment on the fodder production potential of legumes Singh and Trivedi (1981) found that application of 120 kg P_2O_5 ha^{-1} produced the maximum green forage. According to Balakumaran (1981) the yield of haulm in cowpea progressively increased with increase in phosphorus application and the yield was highest for 70 kg P_2O_5 ha^{-1}. Singh *et al.* (1987) observed significant increase in stover yield of maize with the application of 75 per cent as recommended dose of P_20_5 over 50 per cent and no application. Lokanath and Kudasomannavar (1987) noticed that the green fodder yield of lucerne increased numerically with increase in the P level from 50 to 100 kg P_2O_5 ha^{-1} but the increase was not significant.

Mc Ivor *et al.* (1988) found no effect with phosphorus application on yield of verano stylo. Murali (1989) reported that *Sesbania rostrata* produced the maximum green matter yield of 15.85 t ha^{-1} with the application of 30 kg P_2O_5 ha^{-1}.

Munegowda *et al.* (1987) reported that the response of hybrid napier was marked and consistent upto the maximum level of fertilizer (180:120:80 Kg NPK ha^{-1}) which gave an average yield of 23.73 t of green fodder ha^{-1}. Shivanand *et al.* (1987) reported that the green fodder yield increased with successive increase in fertilizer level from 50:30:20, 100:60:40, 150:90:60 kg NPK ha^{-1} in fodder sorghum. Application of recommended fertilizer dose gave 19.0, 47.5 and 98.8 per cent higher fodder yield over the application of 50 per cent, 25 per cent and no fertilizer respectively in hybrid sorghum (Kamat *et al.*, 1991). Thakuria (1993) noticed no significant effect on green fodder yield of teosinte by potassium application. Malavia *et al.* (1998) reported that the green fodder yield of pearl millet significantly increased with each increment of fertilizer level and N_{80} $P_{17.5}$ kg ha^{-1} emerged out as the optimum dose.

2.1.2.2. Dry fodder yield

Ganguli *et al.*(1976) reported that dry matter yield increased with increasing levels of nitrogen in fodder oats. In fodder sorghum application of 150 kg N ha^{-1} scored the maximum dry matter yield (Gupta and Gupta, 1976). Singh *et al.* (1981) observed a significant increase in dry matter yield of maize with the application of 120 kg N ha^{-1}. In pearl millet the dry matter production was 33.9 per cent more by the application of 120 kg N ha^{-1} over no nitrogen. (Munda *et al.,* 1984). Balyan and Singh (1985) noticed a marked increase in dry matter production upto 40 kg N ha^{-1}. Patel and Raj (1988) showed significant increase in dry matter production of Sorghum with increasing levels of N upto 120 kg N ha^{-1}.

In teosinte, significant increase in dry matter yield upto 90 kg N ha^{-1} was observed by Thakuria (1993). In fodder cowpea the dry matter yield was maximum when 20 kg N ha^{-1} was applied (Jena *et al.,* 1995). Application of 120 kg N ha^{-1} resulted in higher dry forage yields in sorghum (Barik *et al.,* 1998). Krishna *et al.* (1998) obtained maximum dry fodder yields in fodder maize with the application of 180 kg ha^{-1}. Ramamurthy and Vindoshankar (1998) reported that application of 50 kg N ha^{-1} recorded significantly higher dry matter yield in Pennisetum trispecefic hybrid compared with 25 kg N ha^{-1} and the control, but it was on par with 75 kg N ha^{-1}. Sonia (1999) noticed that nitrogen application remarkably increased the dry fodder yield of signal grass.

Sandhu *et al.* (1976) reported that in cowpea the production of dry fodder was significantly affected by phosphorus application upto 25 kg P_2O_5. Dry matter accumulation showed a clear trend of increase with increase in the rates of P applied in cowpea. (Balakumaran,1981). Lokanath and kudasomannavar (1987) noticed that the total dry matter yield of lucerne increased numerically with increase in P level from 50 – 100 kg P_2O_5 ha^{-1} but the increase was not significant. Shivanand *et al.* (1987) reported that in fodder sorghum, dry fodder yield, total dry matter and dry matter accumulation into leaf and stem increased with successive increase in fertilizer level from 50:30:20 to 150:90:60 kg NPK ha^{-1}. Application of 100 per cent P_2O_5 close of rice to *Sesbania rostrata* produced the highest drymatter followed by application of 50 per cent P_2O_5 (Halepyati and Sheelavantar, 1989). Murali (1989) indicated that a maximum drymatter yield of 5.08 t ha^{-1} was obtained with the application of 30 kg P_2O_5 ha^{-1} in *Sesbania rostrata*. Raj and Patel (1991) reported that a maximum dry fodder yield of 7.62 t ha^{-1} was obtained with the application of 80 kg P_2O_5 ha^{-1} in cowpea. Thakuria and Luikham (1991) observed that application of phosphorus significantly affected the dry fodder yield upto 50 kg P_2O_5 ha^{-1} in fodder cowpea. Thakuria (1993) reported that application of potash did not give any significant response to fodder yield of teosinte. Coates (1994) found that fertilizer P increased the drymatter yield of pastures of *Stylosanthes hamata* cv. verano. Lira *et al.* (1994) revealed that application of 60 kg N +120 kg P_2O_5 revealed increased the drymatter yield from 2.3 $ha^{-1}cut^{-1}$ with no fertilizers to 4.2 t in signal grass.

2.1.3 Quality

2.1.3.1 Crude Protein content

Hegde and Relwani (1974) reported that crude protein content and yield of fodder sorghum were increased with increasing levels of N. Rathore and Vijayakumar (1977) indicated that application of a higher dose of 160 kg N ha^{-1}gave a significant increase in crude protein content of sorghum over control and 80 kg N ha^{-1}. Stomyayor-Rtos and Lugo-Lopez (1978) expressed that leaf N content of sorghum increased with increased N application. In pearl millet, the crude protein content was increased from 6.09 to 8.13 per cent with increasing levels of N from 20 to 60 kg N ha^{-1} respectively (Tripathi *et al.,* 1979). Thind and Sandhu (1980) reported no significant increase in crude protein content with the application of 120 kg N ha^{-1} in maize. Goudreddy (1982) reported that in rabi sorghum the content of nitrogen in leaf was highest at 30 days after sowing which progressively decreased to a minimum at harvest. Shanmughasundaram and Govindasamy (1984) observed a significant increase in crude protein content of fodder maize from 7.95 to 9.18 per cent with the application of 60 to 90 kg N ha^{-1}. Khader *et al.* (1985) noticed a significant increase in crude protein content with N fertilization in fodder sorghum. Korikanthimath and Palaniappan (1987) observed that in summer, application of nitrogen to sorghum increased the N content in plants upto 30th day and there after it decreased until harvest. Kothari and Saraf (1987) noticed that application of N increased the crude protein content, ash content and *in-vitro* drymatter digestibility of fodder sorghum. In bajra napier hybrid the crude protein content was increased from 8.41 to 9.9 per cent with the application of 150 kg N ha^{-1} (Govindaswamy and Manickam, 1988). Karumadi and Vasuki (1991) observed that the protein content of fodder maize increased due to N application. Safdar (1997) concluded that the protein content of fodder maize improved with increasing levels of nitrogen against control. Krishna *et al.* (1998) recorded higher crude protein content of 10.13 per cent with 180 kg N ha^{-1} compared to control (5.05 %). Thakur *et al.* (1998) found that in maize, N uptake by plants increased significantly with an increase in N level upto 150 kg ha^{-1}.

Application of phosphorus at the rate of 40 kg ha^{-1} increased the crude protein yield from 4.19 to 4.92 g ha^{-1} and it was increased to 5.32 g ha^{-1} at 80 kg P_2O_5 ha^{-1} in fodder cowpea (Bhagwandas *et al.*, 1975). Mariyappan (1978) observed a progressive increase in protein content of

Stylosanthes gracilis with increasing levels of phosphorus upto 120 kg ha^{-1}. Murali (1989) reported that in *Sesbania rostrata* phosphorus application increased the nitrogen content of plant. Rajasree (1994) found that application of moderate levels of lime (125 kg ha^{-1}) in combination with 60 kg P_2O_5 increased the crude protein content of legumes.

Shivanand *et al.* (1987) observed that per day productivity and crude protein level and yield were favourably influenced by fertilizer application in fodder sorghum. In teosinte, P application @ 20 kg P_2O_5 ha^{-1} and K @ 40 kg K_2O ha^{-1} were found to increase the crude protein content (Thakuria, 1993). Sonia (1999) observed an inverse relationship between levels of applied nitrogen and nitrogen content of fodder. Higher levels of applied potassium reduced the nitrogen content of fodder.

2.1.3.2 Phosphorus content

Bahl *et al.* (1970) reported increase in phosphorus content of hay with increase in nitrogen application in black anjan. Monterio and Werner (1977) studied the effect of nitrogen fertilization of guinea grass in Brazil and found that phosphorus content of fodder was reduced by nitrogen application. Rathore and Vijayakumar (1977) noticed a decrease in phosphorus content due to nitrogen application in dinanath grass. The phosphorus content of dinanath grass was found to increase by phosphorus application (Rathore and Vijayakumar, 1978). Abraham *et al.* (1980) observed a decreasing trend in phosphorus content with nitrogen application in dinanath grass. Kamalakumari and Singaram (1996) reported that increasing levels of NPK fertilization increased the uptake of phosphorus and other nutrients in maize. Duraisami and Mani (2000) noticed a profound influence of increasing levels of N in enhancing the P uptake in maize.

Faroda and Tomer (1975) reported that application of 17 kg and 34 kg P_2O_5 ha^{-1} significantly increased the plant phosphorus content and total P uptake over control. Mariyappan (1978) observed that application of phosphorus at the rate of 120 kg ha^{-1} resulted in higher phosphorus content than application of 40 and 80 kg P_2O_5 ha^{-1}. Murali (1989) reported that in *Sesbania rostrata* phosphorus application at the rate of 30 kg ha^{-1} resulted in a plant phosphorus content of 0.65 per cent compared to 0.57 per cent for no application. In fodder cowpea, Thakuria and Luikham (1991) observed significantly higher phosphorus content (0.32 per cent) in plants with the application of 50 kg P_2O_5 ha^{-1}. Rajasree (1994) found that in cowpea and *Sesbania rostrata* application of phosphorus at the rate of 60 kg P_2O_5 ha^{-1} decreased the plant phosphorus content compared to control.

Fernandes *et al.* (1985) noticed a decrease in P concentration in plants with increase in N levels in presence of potassium in signal grass. According to Andrade *et al.* (1996) forage P concentration was decreased by N and K application. Sonia (1999) reported that the phosphorus content of signal grass was not significantly different at various levels of either N and K.

2.1.3.3. Potassium content

According to Reid *et al.* (1967) nitrogen treated herbage at any stage of maturity generally contained higher levels of potassium than grasses without nitrogen. Abraham *et al* (1980) reported an increase in potassium content of dinanath grass (*Pennisetum pedicellatem*) due to application of nitrogen. Baskaran (1993) reported an enhancement in the uptake of K in maize with the addition of inorganic N. In signal grass the K content was not significantly influenced by the different levels of nitrogen (Sonia, 1999).

In fodder cowpea application of 17 and 34 kg P_2O_5 ha^{-1} significantly increased the total uptake and accumulation of potassium (Faroda and Tomer, 1975). Murali (1989) observed that in *Sesbania rostrata* phosphorus application at the rate of 30 kg ha^{-1} recorded highest potassium content of 1.69 per cent. Rajasree (1994) noticed that in cowpea variety C-152 highest K content (1.9 per cent) was recorded with the application of 60 kg P_2O_5 ha^{-1} but in *Sesbania rostrata* application of 60 kg P_2O_5 decreased the plant potassium content.

Munda *et al.* (1984) found that in hybrid pearl millet, potassium uptake was increased by 35.1 and 40.5 per cent due to 120 kg N and 60 kg P_2O_5 ha^{-1} respectively over no application of nitrogen and phosphorus. Dampney (1992) observed that potash application increased the herbage potassium concentration. Sonia (1999) reported that increase in potassium levels from 50 to 100 kg ha^{-1} significantly increased the potassium content of fodder.

2.1.3.4 Crude fibre

Studies conducted by Tiwana *et al.* (1975) in hybrid napier revealed that the crude fibre content was reduced by N application. Rathore and Vijayakumar (1977) found that nitrogen and phosphorus application did not cause any appreciable change in crude fibre content of sorghum. A reduction in crude fibre content of dinanath grass with increased N application was noticed by Abraham (1978). Thomas (1978) from Vellayani noted a significant reduction in crude fibre content of Hybrid napier with the application of nitrogen upto 250 kg N ha^{-1}. Raskar (1978) also reported a negative correlation between N application and crude fibre per cent in maize. Khader *et al.* (1985) found an increase in crude fibre content of fodder sorghum with increase in N application. Karamudi and Vasuki (1991) also reported an increase in crude fibre content of fodder maize with N application. Safdar, (1997) concluded that the fibre content and total ash content of maize improved with increasing levels on N. Krishna *et al.* (1998) reported that increase in N from 0 to180 kg ha^{-1} decreased the crude fibre content in fodder maize. Sonia (1999) concluded that incremental levels of nitrogen reduced the crude fibre content to a significant extent in signal grass.

2.2 Effect of combined application of organic manures and chemical fertilizers on growth, yield and quality of fodder crops

The use of organic manures, apart from helping in improvement of physical and biological properties of the soil, supply of NPK and micronutrients, help in improving the use efficiency of chemical fertilizers (Motsara, 2000).

2.2.1 Growth characters

Atlavinyte and Zimkuviene (1985) observed improved growth in pastures and crops like rye and barley by using worm activated soil. Curry and Boyle (1987) obtained enhanced plant growth in the presence of earthworms, which was attributed to an increased supply of readily available plant nutrients. Shuxin *et al.* (1991) found 30-50 per cent increase in plant growth and 10 per cent increase in height of sugarcane when vermicompost was applied. Application of vermicompost stimulated the root and shoot growth of maize plantlets (Stolyarenko *et al.*, 1992).

According to Kale *et al.* (1991) the level of chemical fertilizers could be brought down to 20-50 per cent when applied with vermicompost. Reddy and Mahesh (1995) observed improved vegetative growth, increased number as well as weight of functional nodules per plant with the application of vermicompost. Babu (1996) reported that plant height and leaf area index of rice was significantly increased with the application of 10 t ha^{-1} of FYM. Gunathilagaraj and Ravignanam (1996) noticed that application of vermicompost significantly increased the shoot length, shoot weight and shoot: root ratio of mulberry saplings. Application of vermicompost @ 2.5 t ha^{-1} increased the plant height of rice (Janaki and Hari, 1997). 25 t ha^{-1} of vermicompost along with full inorganic fertilizer influenced the growth of tomato to the maximum extent (Pushpa and Prabhakumari, 1997). Meera (1998) reported that in cowpea the use of vermicompost either as seed inoculant or as organic manure gives better results in terms of yield as well as growth characters and the quantity of fertilizers can be reduced to half when vermicompost was used as seed inoculant.

Combined application of farmyard manure and nitrogen levels significantly influenced the plant height of pearl millet (Kavimani *et al.*, 2000). Khan *et al.* (2000) reported that application of 5 t farmyard manure per hectare along with 40 kg N ha^{-1} resulted in maximum plant height (218.1 cm) in pearl millet and it was significantly superior to the control and 2.5 t farmyard manure alone. Patil and Bhilare (2000) noticed a significant increase in plant height, and number of tillers of wheat with the application of vermicompost. In cowpea Shailajakumari and Ushakumari (2001) observed that various growth attributes like plant height, number of branches per plant, root : shoot ratio, number of nodules per plant and weight of nodules per plant recorded the maximum value with vermicompost + NPK application.

2.2.2 Dry matter production and yield

Helkiah *et al.* (1981) noticed that application of organic manures at different levels in combination with inorganic fertilizers significantly increased the grain and straw yield of sorghum. Rose and Cairns (1982) found that in rye grass the fodder production was increased by the earthworms by increasing biochemical activity and nutrient recycling in the soil. In pearl millet Gupta *et al.* (1983) noticed 30 per cent higher grain and straw yield with the application of farmyard manure and urea than with farm yard manure alone and nearly equal to that obtained with urea alone. The application of worm worked compost resulted in higher yields of paddy crop ranging from 95 per cent increase in grain and 128 per cent increase in straw (Senapathi *et al.*, 1985). Fierriere and Cruiz (1992) reported that compost produced by earthworms from municipal wastes significantly increased the maize dry matter when used along with fertilizers.

In upland rice Rala and Garcia (1992) observed that maximum yield was produced with the application of 50 per cent N from organic manure + 50 per cent N from inorganic sources. In rye grass vermicompost increased the dry matter yield (Jimenez and Alvarez, 1993). Phule (1993) obtained higher sugarcane yield from vermicompost treated plots than the chemical fertilizers applied plots. Ushakumari *et al.* (1996) found that Package of practice recommendation with cattle manure as organic source, vermicompost as organic source along with half the recommended dose of inorganic fertilizer and vermicompost as the sole source of nutrients, all recorded almost the same yield. Bijulal (1997) reported that in cowpea the treatment vermicompost 20 t ha^{-1} + lime + fertilizer was found superior to all other treatments. Vermicompost along with full inorganic fertilizer increased the yield of cowpea by 19 per cent and the application of vermicompost without inorganic fertilizer was equally effective as that of recommended manurial schedule (Jiji, 1997).

Brijlal and Dhyansingh (1998) found that in fodder cowpea maximum dry fodder yield was obtained for the treatment involving 100 per cent NPK and farmyard manure compared to chemical fertilizers. Jeyabal *et al.*(1998) reported that application of nitrogen through vermicompost + fertilizer gave seven per cent higher yield in maize than entire nitrogen through fertilizer. In sorghum an application of farm yard manure 10 t ha^{-1} + recommended inorganic fertilizer recorded a grain yield increase of 75 per cent compared to control (Parasuraman *et al.*, 1998) Sasirekha *et al.* (1998) noticed that in bajra among the different nitrogen management practices tried, application of 75 kg N ha^{-1} as urea with 2.5 t of farmyard manure per hectare recorded the highest dry fodder yield. In maize, Sharma and Gupta (1998) opined that integration of 75 per cent N through chemical fertilizer + 25 per cent through organic sources gave equal grain yield to that of 100 per cent NPK. Singh and Singh (1999) observed maximum straw and biological yields in wheat with the application of vermicompost 10t ha^{-1}. In lowland rice, the straw yield was found to be high for the treatment which received vermicompost @ 5 t ha^{-1} (Sudha, 1999).

In pearl millet under rainfed condition the maximum fodder yield of 2029 kg ha^{-1} was obtained with the combined application of 5 t ha^{-1} farmyard manure and 40 kg of nitrogen per hectare (Kavimani *et al.*, 2000). Khan *et al.* (2000) reported that application of 5 t farmyard manure ha^{-1} along with 40 kg nitrogen ha^{-1} resulted in maximum grain and stover yields in pearl millet.

2.2.3 Quality and content of nutrients

Bano *et al.* (1987) found that worm cast has all the qualities of a fertilizer and can replace organic manures and also to some extent chemical fertilizers. Tomati *et al.* (1988) also reported that worm casts were rich in available nutrients for plant growth. Application of one tonne of vermicompost could substitute 25 to 50 per cent recommended dose of fertilizers (Sarawad *et al.*, 1996).

Liebhardt (1976) noticed that in corn grains, the crude protein content was significantly higher when 22 t ha^{-1} of organic manure was applied along with chemical fertilizer. Lampkin (1990) reported that produce obtained with the use of vermicompost is nutritionally superior, tastes good, had good texture and have better keeping qualities. Bhawalkar and Bhawalkar (1993) concluded that application of vermi castings as basal dose @ 25 t ha^{-1} would trigger the soil biology and the transition from chemical nutrition to bio-nutrition was quick and without a significant loss in yield. Jimenez and Alvarez (1993) observed that in rye grass the plant nitrogen content was increased with the application of vermicompost and the uptake was proportional to the applied rate. Stephens *et al.* (1994) found that the earthworms would increase the availability and uptake of nutrients from the soil and obtained a significant increase in foliar concentration of N, P, K, Ca, Cu, Na, Mn, Fe and Al in Wheat.

Venkatesh (1995) reported that application of vermicompost @ 5 t ha^{-1} alone or in combination with recommend doses of inorganic fertilizers increased the nutrient content of petioles and improved the yield and quality of Thompson seedless grapes. According to Kamalakumari and Singaram (1996) there was a significant increase in the biomass yield and uptake of major nutrients in maize plots receiving farmyard manure 10 t ha^{-1} in combination with 100 per cent NPK. George and Pillai (1996) noticed that with both vermicompost and farmyard manure addition of each incremental dose of fertilizer caused significant increase in the uptake of nutrients in guinea grass plants.

Vasanthi and Kumaraswamy (1996) obtained highest content of K, Ca, Mg and micronutrients in the treatment that received vermicompost along with NPK fertilizers in rice. According to Shailajakumari and Ushakumari (2001) combined application of vermicompost and chemical fertilizers increased the protein content of grains of cowpea.

2.2.4 Uptake of nutrients

Sharma and Mittra (1988) noticed higher uptake of nitrogen by rice with application of organic manures along with increasing doses of inorganic nitrogen Zaoshi-Wei and Huong Fu-Zhan (1988) demonstrated that in wheat and sugarcane, chemical fertilizer application along with vermicompost increased the nutrient uptake and net production. Kale *et al.* (1989) found significantly higher levels of uptake of N and P in rye treated with vermicompost. Sarkar *et al.* (1989) reported that when organic manures are applied in conjunction with optimal doses of NPK it resulted in highest K uptake by crops. Singh and Tomar (1991) noticed a positive effect on the uptake of N with the application of farmyard manure and K in wheat crop.

In sugarcane Shuxin *et al.* (1991) observed 30-50 per cent increase in N uptake with the application of vermicompost. The nutrients present in the worm casts are readily soluble in water for the uptake of plants (Bhawalkar and Bhawalkar, 1993).

Syres and Springett (1984) reported that application of vermicompost enhanced the phosphatase activity in soil, which in turn improved the phosphorus availability to plants. Zachariah (1995) observed an increased K uptake in vermicompost applied plants. Gunathilagaraj and Ravignanam (1996) reported that vermicompost significantly increased the N, P, K uptake of mulberry. The presence of vermicompost also enhanced the micronutrients uptake by the plants. Brijlal and Dhyansingh (1998) obtained maximum K uptake in fodder cowpea and maize by growing in 100 per cent NPK and farmyard manure (15 t ha^{-1}) applied plots compared to chemical fertilizers alone. Sharma and Gupta (1998) reported that application of 75 per cent NPK through chemical fertilizers + 25 per cent N through organic sources like farmyard manure increased the uptake of N, P and K in maize.

2.3 Effect of combined application of organic manures and inorganic fertilizers on the physico-chemical properties of soil

2.3.1 Soil physical properties

Continuous application of farmyard manure in combination with chemical fertilizers proved to be beneficial in improving the water holding capacity of soil (Prasad and Singh, 1980). Sinha *et al.* (1980) observed that application of farmyard manure in combination with chemical fertilizers decreased the bulk density of soil where as continuous use of chemical fertilizers alone increased the bulk density. Helkiah *et al.* (1981) recorded the lowest bulk density (1.25 g cc^{-1}) with the application of 30 t ha^{-1} of farmyard manure in conjunction with half the recommended dose of inorganic fertilizers when compared with the application of inorganic fertilizers alone in black soil for jowar crop. Vermicompost enhances the soil structure and improves the water holding capacity and porosity of soil to facilitate the root respiration and growth (Lee, 1985). Lal and Mathur (1989) observed a decrease in bulk density with organics either alone or in conjugation with inorganics where as inorganics alone increased it.

Bulk density of the soil was significantly and negatively correlated to the organic carbon content (Brar, 1991). George (1996) reported that vermicompost application lowered the bulk density of the soil and increased the water holding capacity and available N, P and K in the soil. Integrated use of recommended dose of fertilizer and farmyard manure at the rate of 5t ha^{-1} did not produce any appreciable change among various soil physical properties (Madhu *et al.*, 1996). They are also reported that continuous use of inorganic fertilizers have a depressing effect on the soil pH. Sarawad *et al.* (1996) found that physical properties of vertisol were improved with vermicompost application. Sheeba and Chellamuthu (1996) reported that application of 100 per cent NPK + farmyard manure decreased the bulk density and increased the water holding capacity. Sharma and Gupta (1998) noticed a significant increase in water holding capacity of soil when 100 per cent NPK was applied in combination with organic manure.

2.3.2 *Soil chemical properties*

According to Liebhardt (1976) there was a significant decrease in the soil K on maize plots receiving high rates of organic manure but this reduction was less apparent when organic manure was applied along with inorganic fertilizers. Mathen *et al.* (1978) observed that combined application of farmyard manure and inorganic fertilizer had little influence on available nitrogen content of soil. Kurumthottical (1982) revealed that application of phosphatic fertilizers in combination with organics in rice has resulted in higher content of available P as compared to inorganic fertilizer alone. Lal and Vleeschauwer (1982) reported increased concentrations of available and exchangeable K content in casts compared to surrounding soil. Tomati *et al.* (1985) found that earthworms could consume all the organic wastes and reduce their volume by 40-60 per cent. As a result, castings with a high fertility value could be produced. Remarkable quantities of available nutrients, a large microbial population and biologically active metabolites particularly giberellins, cytokinins, auxins were also found.

Saravanan *et al.* (1987) reported that the *in situ* pH of soil was not influenced by the combined application of bio-organics and chemical fertilizers, but a decreasing trend towards neutrality was noted upto 45 days after transplanting. Sharma *et al.* (1987) observed that the application of farmyard manure resulted in a significant increase in soil pH.

Nair (1988) noticed that application of farmyard manure along with nitrogen fertilizer did not produce any influence on the soil chemical properties seeds as available nitrogen, available P_2O_5 and available K_2O contents of soil after harvest. Combined application of farmyard manure and chemical fertilizers increased N, P and K contents of the soil (Biswas and Benbi, 1989). Combination of organic manure with inorganic fertilizers had a moderating effect on soil reaction, particularly under acidic soil and improvement in sustained availability of N, P, K, S and the micronutrients particularly Zinc (Nambiar and Abrol, 1989). Budhar *et al.* (1991) obtained increased post harvest nutrient status of soil NPK with the application of 5t ha^{-1} of organic manure along with 100 per cent recommended fertilizer in low land rice. Shuxin *et al.* (1991) reported that the increased P availability was by an increase in solubility of P by higher phosphatase are activity in the presence of vermicompost. Bhawalkar (1992) observed that vermicompost application resulted in 37 per cent more nitrogen, 66 per cent more P_2O_5, 10 per cent more K_2O, 50 per cent less electrical conductivity and 46 per cent less chlorides than inorganic fertilization while studying the effect of vermicompost on sugarcane yield.

Kale *et al.* (1992) tested the possibility of reducing the use of chemical fertilizers by using vermicompost as organic fertilizer on the summer crop of paddy and concluded that the vermicompost application enhanced the activity of selected microbes in the soil system and there was high level of total nitrogen in the experimental plot receiving half the recommended dose of chemical fertilizers and vermicompost. Raut and Malewar (1995) reported the richness of vermicompost in N, P, K, Ca, Mg and micronutrient content over farmyard manure.

Kamalakumari and Singaram (1996) noted that application of farmyard manure 10 t ha^{-1} + 100 per cent NPK in maize registered maximum organic carbon content which was significantly higher than application of chemical fertilizers alone. George (1996) reported higher available N, P and K in soil with vermicompost application. In sorghum application of vermicompost increased the organic carbon content and available P status of soil (Sarawad *et al.*, 1996).

Vasanthi and Kumaraswamy (1996) noticed that in rice, application of vermicompost + NPK improved the organic carbon content and available status of N, P, K, Ca, Mg and micronutrients compared to treatment with NPK alone. Parasuraman *et al.* (1998) reported that application of farmyard manure 10 t ha^{-1} + recommended inorganic fertilizer in sorghum increased the available nutrients in soil (N, P and K) than recommended inorganic fertilizers alone. Sharma and Gupta (1998) observed a remarkable increase in organic carbon content and available N and P status of the soil when 100 per cent NPK was applied in combination with organic manure.

Rajasree (1999) noticed that when organic manure was used in equal or in higher proportion with chemical nitrogen source, it showed moderating effect on the soil acidity. Sudha (1999) reported that in rice the highest NPK level along with 10 t ha^{-1} farmyard manure recorded the highest P_2O_5 status of soil where as the same rate with 5 t ha^{-1} vermicompost recorded the highest K_2O status of soil.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was carried out to evaluate the production potential and quality of different fodder crops in summer rice fallows under different nutrient levels, to study the changes in physico-chemical properties of soil due to fodder cropping and also to evaluate the economics of fodder production in summer rice fallows. Cereal and leguminous fodder crops were raised in summer rice fallows during February-May, 2000.

The details of the materials used and methods followed are presented in this chapter.

3.1 Materials

3.1.1. Experimental site

The experiment was conducted at Cropping Systems Research Centre, Karamana, Thiruvananthapuram, a sub station under NARP (Southern region) of Kerala Agricultural University, located at 8.5^0 N latitude and 76.9^0 E longitude and at an altitude of 29 m above the mean sea level.

3.1.2 Soil

The soil of the experimental area was sandy loam, acidic in reaction, low in CEC, high in organic carbon, low in available nitrogen and medium in available phosphorus and potassium. The important physicochemical properties and the pH of the soil are presented in Table 3.1

Table 3.1. Soil characteristics of the experimental site

A. Mechanical composition

Parameter	Content in soil (%)	Method used
Coarse sand, Fine sand	74.28	Bouyoucos Hydrometer Method (Bouyoucos, 1962)
Silt	8.74	
Clay	17.87	
Soil texture	Sandy loam	
Bulk density (gcc^{-1})	1.34	International pipette method (Gupta and Dakshinamoorthy, 1980)
Water holding capacity (%)	20.05	

B. Chemical composition

Parameter	Content	Method
pH	5.3	pH meter with glass electrodes (Jackson,1973)
EC (dSm^{-1})	0.016	Conductivity bridge
CEC (cmol (p) kg^{-1})	6.84	Buchner funnel method (Jackson, 1973)
Organic carbon (%)	1.19	Walkley and Black's rapid titration method (Jackson, 1973)
Available N (kg/ha)	244.0	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg/ha)	26	Bray colorimetric method (Jackson, 1973)
Available K_2O (kg/ha)	162	Ammonium acetate method (Jackson, 1973)

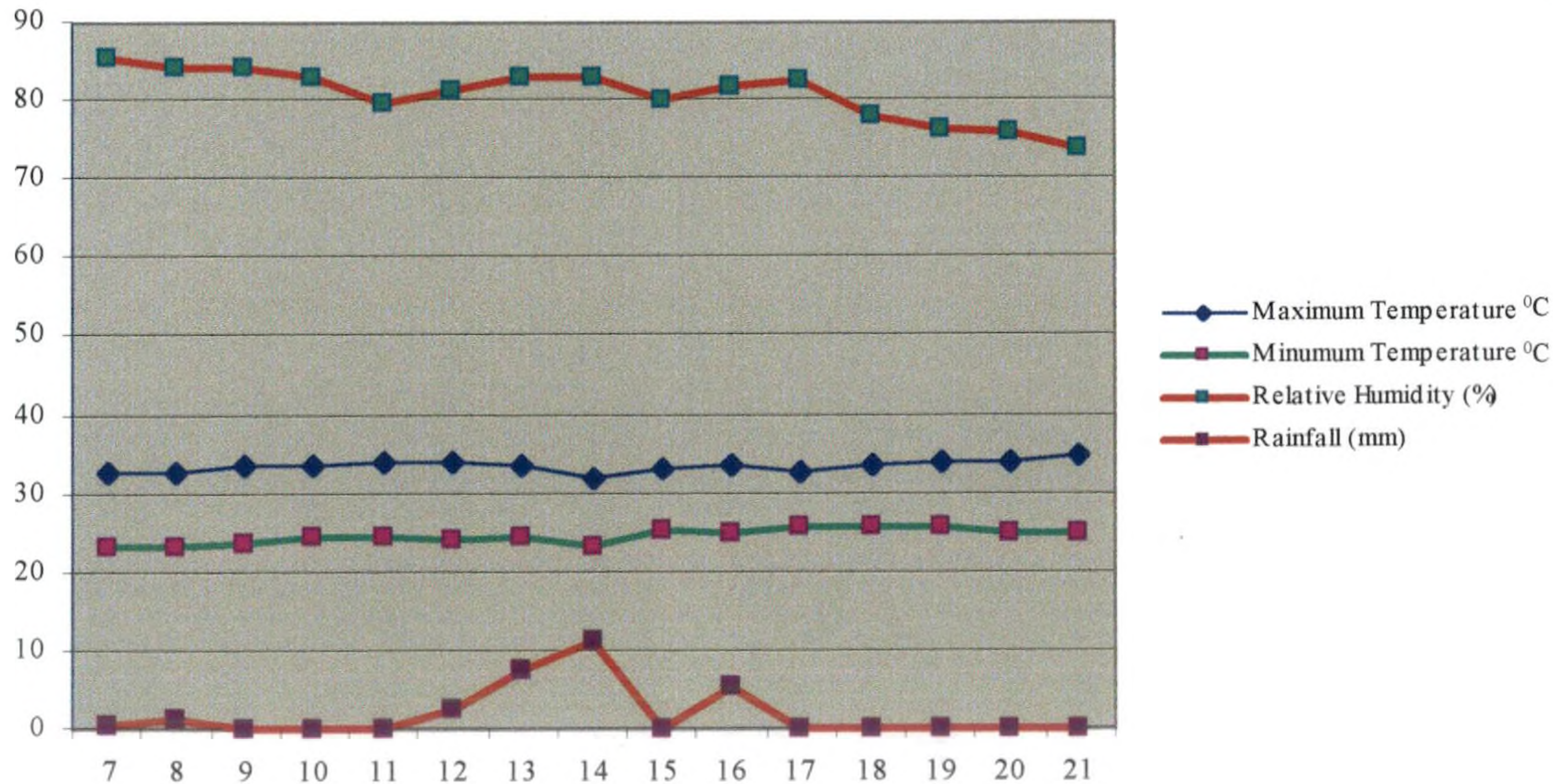
3.1.3 Cropping history of the field

The experimental area was under bulk crop of paddy before the experiment.

3.1.4 Meteorological parameters

Data on weather conditions like temperature, rainfall and relative humidity were obtained from Indian meteorological department observatory, Thiruvananthapuram. The average values of climatic

Fig. 1. Weather parameters during the crop period – weekly averages (February to May 2000)



parameters during the cropping period are given in Appendix I and graphically presented in Fig. 1.

In general weather conditions were favourable for the satisfactory growth of the crop.

3.1.5 Season

The field experiment was conducted during the period from 15-2-2000 to 23-5-2000.

3.1.6 Seed materials

3.1.6.1 Cereal fodders

Sorghum and bajra were the cereal fodders used for the experiment. Both are fairly drought resistant and tolerant to wide variations in soil and moisture conditions. The desirable attributes of sorghum and bajra include high forage yield, ratooning ability, high quality fodder and acceptability by the animals.

The seeds were obtained from the Department of Forage Crops, Tamil Nadu Agricultural University, Coimbatore.

3.1.6.2 Legume fodder

Cowpea and *Sesbania rostrata* were the two fodder legumes used for the experiment. Cowpea variety C-152 was used. It is largely recommended as a grain crop for cultivation in rice fallows. Studies under AICRP on forage crops, Vellayani showed its suitability for fodder purpose also. Seed material of this variety was obtained from National Seeds Corporation.

Sesbania rostrata is widely used as green manure crop. It has both stem and root nodules and have high biomass production capacity. Reports from AICRP centre. Rajendra Nagar indicated that *Sesbania rostrata* had a high crude protein content (32 per cent) and good digestibility and satisfactory cattle acceptance as a green fodder in combination with cereal fodders. The seeds of *Sesbania rostrata* obtained from Department of Agronomy, College of Agriculture, Vellayani.

3.1.7 Manures and Fertilizers

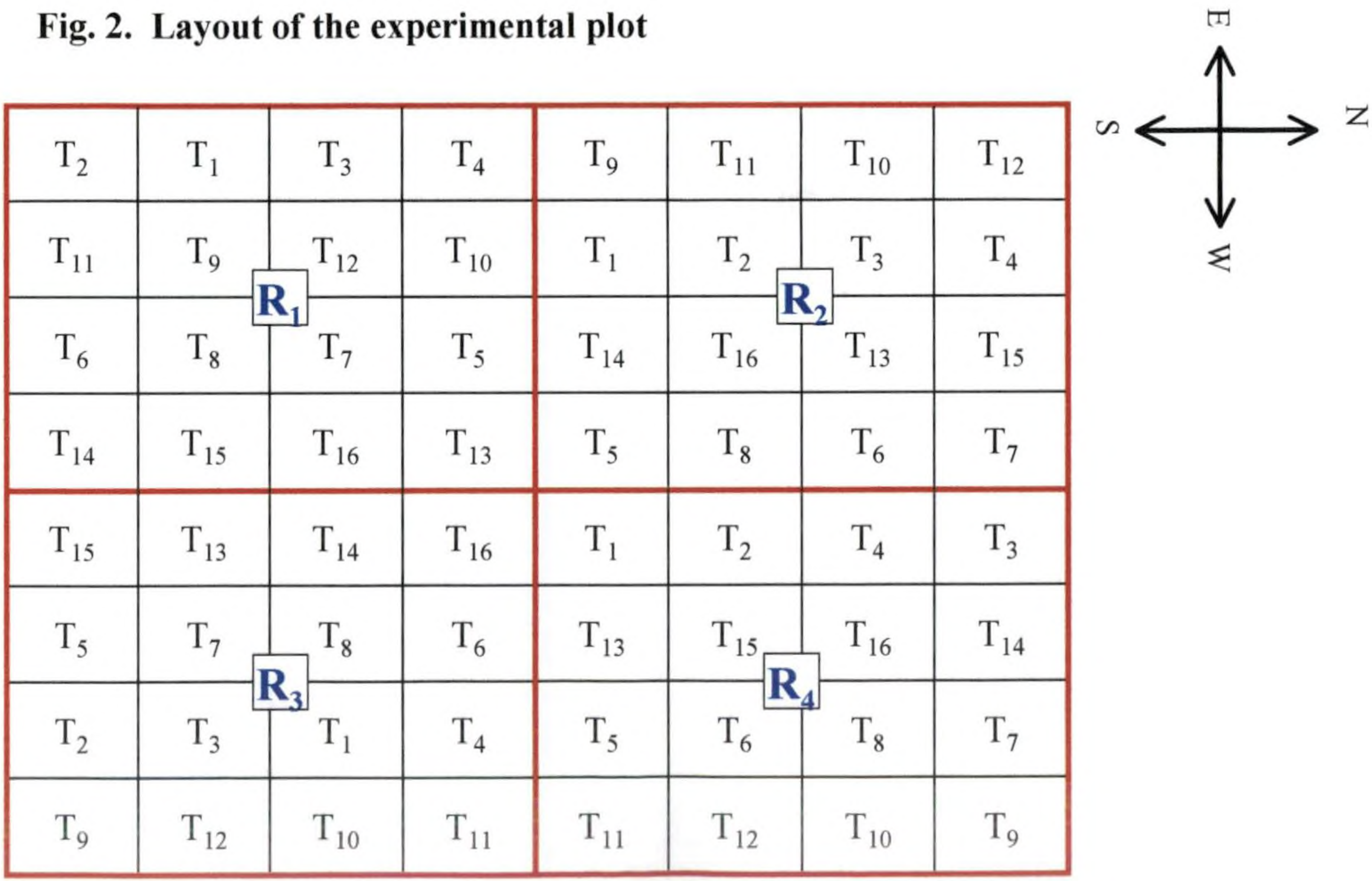
3.1.7.1 Organic manures

Vermicompost (1.16 : 0.67 : 2.02) per cent NPK obtained from College of Agriculture, Vellayani was used as organic manure.

3.1.7.2 Chemical fertilizer

Urea (46 per cent N), mussoriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as inorganic sources of N, P_2O_5 and K_2O, respectively.

Fig. 2. Layout of the experimental plot



3.2 Methods

3.2.1 Design and Layout

The experiment was laid out in Split plot design with four replications. The details are given below.

Design	: Split Plot design
Treatments	: 16
Replications	: 4
Total number of plots	: 64
Gross plot size	: 3 x 3 m

Spacing

Cereal fodders	: 45 x 15 cm
Fodder legumes	: 30 x 15 cm

3.2.2 Treatments

Main plot factors – Fodder crops

c_1 – Fodder Bajra – *Pennisetum typhoides*

c_2 – Fodder sorghum – *Sorghum bicolor*

c_3 – *Sesbania rostrata*

c_4 – Fodder cowpea – *Vigna unguiculata*

Sub plot factors : Four combinations of the following

Organic manure – Two levels

v_1 – Vermicompost (VC) @ 2.5 t ha^{-1}

v_2 – Vermicompost (VC) @ 5 t ha^{-1}.

Fertilizers – Two levels

f_1 – 50 per cent of Package of Practice (POP) Recommendation

f_2 – 100 per cent of Package of Practice (POP) Recommendation

NOTE: Recommended dose of fertilizers for fodder bajra and sorghum is 60:40:20 and for fodder cowpea and *Sesbania rostrata* is 25:60:30 kg NPK ha^{-1}.

Treatment combinations

1. ($c_1v_1f_1$) – Bajra + VC 2.5 t ha^{-1} + 50 per cent POP
2. ($c_1v_1f_2$) – Bajra + VC 2.5 t ha^{-1} + 100 per cent POP
3. ($c_1v_2f_1$) – Bajra + VC 5 t ha^{-1} + 50 per cent POP
4. ($c_1v_2f_2$) – Bajra + VC 5 t ha^{-1} + 100 per cent POP
5. ($c_2v_1f_1$) – Sorghum + VC 2.5 t ha^{-1} + 50 per cent POP
6. ($c_2v_1f_2$) – Sorghum + VC 2.5 t ha^{-1} + 100 per cent POP
7. ($c_2v_2f_1$) – Sorghum + VC 5 t ha^{-1} + 50 per cent POP
8. ($c_2v_2f_2$) – Sorghum + VC 5 t ha^{-1} + 100 per cent POP
9. ($c_3v_1f_1$) – *Sesbania rostrata* + VC 2.5 t ha^{-1} + 50 per cent POP
10. ($c_3v_1f_2$) – *Sesbania rostrata* + VC 2.5 t ha^{-1} + 100 per cent POP
11. ($c_3v_2f_1$) – *Sesbania rostrata* + VC 5 t ha^{-1} + 50 per cent POP

12. ($c_3v_2f_2$) – *Sesbania rostrata* + VC 5 t ha^{-1} + 100 per cent POP

13. ($c_4v_1f_1$) – Cowpea + VC 2.5 t ha^{-1} + 50 per cent POP

14. ($c_4v_1f_2$) – Cowpea + VC 2.5 t ha^{-1} + 100 per cent POP

15. ($c_4v_2f_1$) – Cowpea + VC 5 t ha^{-1} + 50 per cent POP

16. ($c_4v_2f_2$) – Cowpea + VC 5 t ha^{-1} + 100 per cent POP

3.3 Details of cultivation

3.3.1 Field preparation

The experimental site was ploughed, clods broken, cleared off stubbles and plots were laid out with bunds all round. Individual plots were again dug and perfectly levelled.

3.3.2 Manures and fertilizers

Vermicompost was applied to all the plots as per the treatments N, P_2O_5 and K_2O were applied in the form of urea, mussoriephos and MOP 50 per cent and 100 per cent of the recommended doses of N, P_2O_5 and K_2O were given at the time of sowing (as per the package of practice recommendations of the Kerala Agricultural University) to the respective plots as per the treatments.

A

B

Plate 1. Overall view of the experiment

3.3.3 Sowing

The seeds of fodder bajra and sorghum were sown in lines at a spacing of 45 x 15 cm and for fodder cowpea and *Sesbania rostrata* the spacing adopted was 30 x 15 cm. Sowing was done on 15-2-2000. One life irrigation was given immediately after planting to facilitate better establishment. At the end of sowing soil was compacted between rows.

3.3.4 After cultivation

Seed germination was satisfactory. Within two weeks of germination, thinning and gap filling were done wherever necessary.

General conditions of crops were satisfactory throughout the period. Intercultivation and hand weeding operations were carried out wherever necessary.

3.3.5 Harvest

Fodder legumes were harvested on 5-4-2000 (51 DAS) at 50 per cent flowering. Harvesting of bajra was done on 11-4-2000 (57 DAS) at 50 per cent flowering. Fodder sorghum was harvested after complete flowering of plants. The crop became ready for harvest at 100 DAS (23-5-2000).

3.4 Observations

Observations were taken on important parameters associated with growth and yield of fodder crops. Five plants were selected randomly from each plot for the purpose of study and observations were recorded at 20 days interval and at the time of harvest.

3.4.1 Growth characters

3.4.1.1 Height of the plant

The height of the plants was measured from the base of the plant to the tip of top most leaf in the case of fodder bajra and sorghum.

In the case of fodder cowpea and *Sesbania rostrata* the height was measured from the base to the growing tip of tallest branch. The mean plant heights were worked out and expressed in centimeters.

3.4.1.2 Leaf area index (LAI)

Leaf area was measured at 20 days interval and at the time of harvest using LI-300 leaf area meter and expressed in square centimeters. Leaf area index was worked out using the equation given by Watson (1952).

$$LAI = \frac{\text{Leaf area / plant (cm}^2\text{)}}{\text{Land area occupied by the plant}}$$

3.4.1.3 Leaf : stem ratio

Five plants were uprooted carefully from each plot at 20 days interval and at the time of harvest. Each plant was separated into leaves and stem and dried to a constant weight in hot air oven at 68 - 70°C. Dry weight of stem and leaves were recorded separately for each plant and ratio was worked out. The means were then found out and expressed as unit of leaf weight/unit of stem weight.

3.4.2 Yield

3.4.2.1 Green fodder yield

The green fodder yield from the net plot area was recorded immediately after each harvest and the total green fodder production in t/ha was worked out.

3.4.2.2 Dry fodder yield

Five sample plants were collected from each plot and weighed to determine the fresh weight. Cut into small pieces, sun dried and then oven dried to a constant weight at 70°C. The dry matter content for each treatment was computed and the dry fodder yield worked out from the respective green fodder yields.

3.4.3 Plant Analysis

Plant samples were analysed for nitrogen, phosphorus, and potassium at different stages of growth. The plants were chopped and dried in a hot air oven at 80 ± 5^{0}C separately till constant weights were obtained. Samples were then ground to pass through 0.5mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in a physical balance and analysed.

3.4.3.1 Total N content

The nitrogen content in plant was estimated by modified Microkjeldahl method (Jackson, 1973).

3.4.3.2 Total P content

The P content in plants were estimated colorimetrically by Vanado molybdo phosphoric yellow colourimethod (Jackson, 1973) using Spectrophotometer.

3.4.3.3 Total K content

The K content in plants was estimated by the flame photometric method. (Jackson, 1973).

3.4.3.4 Crude Protein content

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

3.4.3.5 Crude fibre content

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

3.4.4 Uptake studies

The total uptake of N, P and K by the fodder crops, during crop growth period was calculated as the product of the content of these nutrients in plant samples and the respective dry weights and expressed as kg ha^{-1}.

3.4.5 Soil analysis

3.4.5.1 Physical properties of soil

Bulk density and water holding capacity

Core samples were collected from 0 – 15 cm depth and analysed for bulk density and water holding capacity as described by Gupta and Dakshinamoorthy (1980).

3.3.5.2 Chemical properties

Soil samples were taken from experimental area before and after the experiment. Composite samples were collected from each plot, air dried, powdered and passed through a two millimetre sieve and analysed for available N, available P_2O_5 and available K_2O as per the standard analytical methods described below.

Organic carbon

Organic carbon content of soil was estimated by Walkley and Black's rapid titration method (Jackson, 1973).

Available N

Available N status of soil was estimated using alkaline potassium permanganate method (Subbiah and Asija, 1956).

Available P_2O_5

Available P status was estimated by Bray colorimetric method (Jackson, 1973).

Available K_2O

Available K status of soil was estimated by neutral normal ammonium acetate method (Jackson, 1973).

3.4.6 Economic Analysis

The economics of cultivation was worked out from the cost of cultivation and the income derived from the treatments.

$$\text{Benefit Cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.4.7 Statistical analysis

The analysis of variance technique (Cochran and Cox, 1965) was used for the comparison of treatment effects for each of the character. The growth characters and nutrient content of fodder crops were analysed separately using the methods of analysis of randomized block design. For the yield, quality characters and uptake of different nutrients, the main effects (V and F) and interaction effects (V x F) among the four treatment combinations were also worked out. For the test of significance of soil analysis data, the analysis of split plot design (Cochran and Cox, 1965) was carried out by combining the observations of the four fodder crops. The critical difference (CD) at five per cent level of significance was calculated wherever a significant difference among the treatments was noticed.

RESULTS

4. RESULTS

An experiment was conducted at the Cropping Systems Research Centre (CSRC), Karamana, Thiruvananthapuram during the period from February – May, 2000. The objectives of the experiment were to study the effect of different nutrient levels on the production potential and quality of cereal and leguminous fodder crops raised in summer rice fallows and to work out the economics of fodder production in summer rice fallows. The changes in physico-chemical properties of soil due to fodder cropping were also studied. The data collected were statistically analysed and the results are presented here.

4.1 Growth characters

4.1.1 Plant height (Table 4.1)

In bajra, integrated application of vermicompost and chemical fertilizers in various combinations significantly influenced the plant height only at the time of harvest. The highest dose of vermicompost combined with the highest dose of fertilizers (v_2f_2) recorded the highest plant height (127.7 cm) and it was significantly superior to all other treatments. At 20 DAS and 40 DAS, v_2f_2 recorded the maximum plant height, but no significant difference was observed between treatments.

Table 4.1 Plant height (cm) of different fodder crops as influenced by the vermicompost fertilizer combinations

Bajra

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	27.10	60.93	92.65
v_1f_2	28.65	61.05	100.38
v_2f_1	29.55	61.75	114.10
v_2f_2	30.10	73.45	127.70
F	NS	NS	47.75**
CD	--	--	7.16

Sorghum

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
v_1f_1	29.25	56.28	99.83	131.35	153.00
v_1f_2	30.25	62.20	104.85	132.73	166.83
v_2f_1	31.35	72.28	105.80	145.60	176.05
v_2f_2	31.45	78.03	115.50	153.28	190.03
F	NS	64.28**	NS	NS	34.37**
CD	--	3.90	--	--	8.49

Sesbania rostrata

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	19.90	76.25	96.80
v_1f_2	20.40	89.35	112.45
v_2f_1	20.50	94.38	119.78
v_2f_2	20.83	105.95	126.13
F	NS	21.79**	47.52**
CD	--	8.43	5.86

Cowpea

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	30.10	48.80	76.10
v_1f_2	30.15	51.10	83.00
v_2f_1	30.90	51.80	85.33
v_2f_2	31.60	53.45	105.70
F	NS	NS	29.18**
CD	--	--	7.54

In sorghum, the data revealed that plant height was favourably influenced by various treatments at 40 DAS and at harvest. Maximum plant height was recorded with the application of vermicompost 5 t ha^{-1} and 100 per cent POP recommendation (v_2f_2) at both the stages. *viz.*, 40 DAS and at harvest (78.03 cm and 190.03 cm respectively). At 20 DAS, 60 DAS and 80 DAS application of different nutrient levels had no significant influence on the plant height though v_2f_2 recorded the maximum plant height.

In the case of *Sesbania rostrata* taller plants were produced with the application of highest dose of vermicompost and chemical fertilizers (v_2f_2) at 40 DAS (105.95 cm) and at harvest (126.13 cm). v_2f_2 was significantly superior to all other treatments. At 20 DAS different nutrient levels could not produce any significant change in plant height.

The results revealed that in cowpea increase in nutrient levels increased the plant height significantly at the time of harvest. Application of vermicompost 5 t ha^{-1} and 100 per cent POP recommendation (v_2f_2) recorded the maximum plant height (105.7 cm) at this stage and v_1f_1 recorded the minimum plant height. Different nutrient levels could not significantly influence the plant height at early stages of growth.

4.1.2 Leaf Area Index (Table 4.2)

In bajra, significant influence of different nutrient levels on LAI was noticed only in the last stage of observation. LAI increased with increasing levels of vermicompost and chemical fertilizers and maximum value (1.505) was obtained with the application of highest dose of vermicompost and chemical fertilizers (v_2f_2) and was significantly superior to other treatments. At 20 DAS and 40 DAS no significant difference was noticed between treatments.

In sorghum, a significant influence on nutrient levels on LAI was observed only at 60 DAS. A progressive increase in LAI from 1.044 to 1.565 was recorded with increase in the levels of vermicompost and chemical fertilizers at 60 DAS.

The LAI at 20 DAS and at harvest were profoundly influenced by various treatments in *Sesbania rostrata*. It was observed that maximum LAI was produced with the application of vermicompost 5 t ha^{-1} and 100 per cent POP recommendation (v_2f_2) at these stages (0.464 and 3.73 respectively). v_1f_1 recorded the minimum LAI at 20 DAS (0.264) and at harvest (2.62).

In cowpea, significant influence of different nutrient levels on LAI was noticed at 40 DAS and at harvest. No significant difference was noticed at 20 DAS. At 40 DAS and at harvest, v_2f_2 recorded the highest

Table 4.2 Leaf area index of different fodder crops as influenced by the vermicompost fertilizer combinations.

Bajra

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	0.070	0.676	0.868
v_1f_2	0.101	0.621	0.946
v_2f_1	0.110	0.714	1.220
v_2f_2	0.114	0.722	1.505
F	NS	NS	23.71**
CD	--	--	0.194

Sorghum

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
v_1f_1	0.068	0.464	1.044	1.530	1.570
v_1f_2	0.092	0.551	1.264	1.590	1.690
v_2f_1	0.101	0.847	1.493	1.660	1.795
v_2f_2	0.102	0.597	1.565	1.670	1.840
F	NS	NS	316.7**	NS	NS
CD	--	--	0.043	--	--

Sesbania rostrata

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	0.264	1.697	2.620
v_1f_2	0.282	1.769	3.196
v_2f_1	0.390	1.771	3.513
v_2f_2	0.464	1.996	3.730
F	48.37**	NS	16.31**
CD	0.043	--	0.382

Cowpea

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	0.716	2.624	4.480
v_1f_2	0.821	3.170	4.569
v_2f_1	0.846	3.490	5.521
v_2f_2	1.086	3.810	5.850
F	NS	32.89**	102.69**
CD	--	0.282	0.216

LAI (3.81 and 5.85 respectively) and v_1f_1 recorded the lowest LAI (2.624 and 4.48 respectively).

Among the four fodder crops, cowpea recorded the highest LAI followed by *Sesbania rostrata*. Bajra recorded the lowest LAI at the time of harvest. LAI of all the crops showed a progressive increase from 20 DAS to harvest.

4.1.3 Leaf : Stem ratio (Table 4.3)

In bajra, it was seen that at 20 DAS and at 40 DAS no significant difference in leaf stem ratio was noticed between various treatments. Significant difference was observed only at the time of harvest. Maximum leaf : stem ratio (0.83) was registered with the application of highest level of vermicompost and chemical fertilizers (v_2f_2) which was on par with v_2f_1 (0.71).

In sorghum, the different levels of vermicompost and chemical fertilizers significantly influenced the leaf : stem ratio at 40 DAS and at harvest. No significant difference in leaf : stem ratio was observed at 20 DAS, 60 DAS and at 80 DAS.

It was seen that application of vermicompost 5 t ha^{-1} and 100 per cent POP recommendation (v_2f_2) produced the maximum leaf : stem ratio (3.06 and 0.97 respectively) at 40 DAS and at harvest and v_2f_2 was

Table 4.3 Leaf : Stem ratio of different fodder crops as influenced by the vermicompost fertilizer combinations

Bajra

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	2.01	0.86	0.61
v_1f_2	2.24	1.16	0.67
v_2f_1	2.58	1.19	0.71
v_2f_2	2.83	1.47	0.83
F	NS	NS	6.37*
CD	--	--	0.12

Sorghum

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
v_1f_1	3.22	2.07	1.68	0.61	0.70
v_1f_2	3.43	2.42	1.80	0.72	0.82
v_2f_1	3.68	2.71	2.33	0.84	0.92
v_2f_2	4.33	3.06	2.34	0.87	0.97
F	NS	90.31**	NS	NS	31.55**
CD	--	0.14	--	--	0.07

Sesbania rostrata

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	1.03	0.75	0.58
v_1f_2	1.04	0.81	0.64
v_2f_1	1.06	0.91	0.68
v_2f_2	1.09	0.94	0.76
F	NS	NS	270.22**
CD	--	--	0.02

Cowpea

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	1.41	1.33	0.89
v_1f_2	1.46	1.43	1.08
v_2f_1	1.52	1.44	1.17
v_2f_2	1.65	1.40	1.51
F	NS	NS	4.63*
CD	--	--	0.39

significantly superior to all other treatments at 40 DAS. At harvest, v_2f_2 was on par with v_2f_1.

Leaf : stem ratio was significantly influenced by different nutrient levels at the time of harvest in *Sesbania rostrata*. At harvest the maximum leaf : stem ratio (0.76) was recorded under the highest level of vermicompost and fertilizers (v_2f_2) and the minimum value (0.58) was registered by v_1f_1. Different nutrient levels could not influence the leaf : stem ratio during the early stages of growth.

Different levels of vermicompost and chemical fertilizers had no significant influence on the leaf : stem ratio of cowpea at early stages of growth. But at the time of harvest, significant difference between treatments were noticed. It was observed that maximum leaf stem ratio (1.51) at harvest was produced by plants receiving vermicompost 5 t ha^{-1} and 100 per cent POP (v_2f_2) and this was on par with v_2f_1.

Leaf stem ratio of all the four crops showed a decreasing trend towards harvest. Maximum value for leaf stem ratio was obtained at 20 DAS and the least value at harvest. Among the four fodder crops the highest leaf stem ratio at harvest was recorded by cowpea followed by sorghum. *Sesbania rostrata* recorded the lowest leaf stem ratio.

4.2 Yield

4.2.1 Green fodder yield (Table 4.4)

Different levels of vermicompost significantly influenced the green fodder yield of fodder bajra. Fertilizer application could not record any significant change in green fodder yield. V x F interaction was also not significant. Highest level of vermicompost (v_2) recorded the maximum green fodder yield of 7533.26 kg ha^{-1}. Even though V x F interaction was not significant. The treatment receiving vermicompost 5 t ha^{-1} and 100 per cent POP (v_2f_2) recorded the highest green fodder yield (7779.48 kg ha^{-1}).

Application of vermicompost at different levels favourably influenced the green fodder yield of sorghum. Fertilizer application and V x F interaction could not record any significant influence on green fodder yield. The treatment v_2 recorded the highest green fodder yield (10791.12 kg ha^{-1}) and v_1 recorded an yield of 9192.61 kg ha^{-1}. The highest green fodder yield (11573.13 kg ha^{-1}) was obtained with the application of v_2f_2 among the combinations.

In *Sesbania rostrata* also various levels of vermicompost produced significant difference in green fodder yield. Different fertilizer levels also showed a significant influence on green fodder yield. V x F interaction was not significant. v_2 (5 t ha^{-1}) registered the maximum

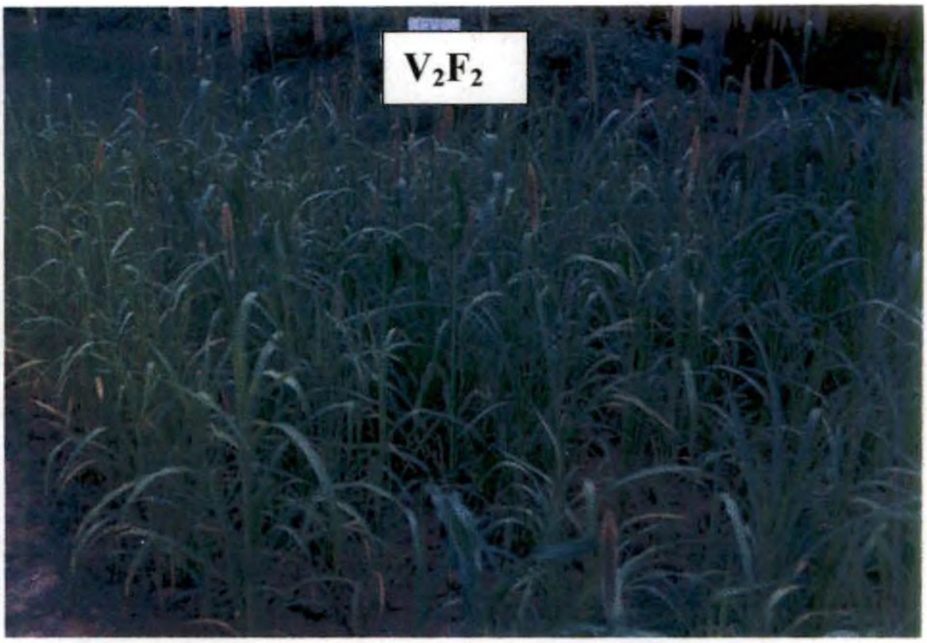
Table 4.4 Green fodder yield (kg ha^{-1}) of fodder crops as influenced by vermicompost fertilizer combinations

	Bajra			Sorghum			*Sesbania rostrata*			Cowpea		
	v_1	v_2	F-mean	V_1	V_2	F-mean	v_1	v_2	F-mean	v_1	v_2	F-mean
f_1	4772.26	7287.05	6029.65	8817.44	10009.12	9413.28	15860.98	16589.37	16225.18	20244.45	24199.36	22221.91
f_2	6907.99	7779.48	7343.74	9567.78	11573.13	10570.45	16583.15	18669.64	17626.14	21566.22	24518.40	23042.31
V-mean	5840.13	7533.26		9192.61	10791.12		16222.07	17629.51		20905.34	24358.88	
	CD V- 1529.69 F-NS VF-NS			CD V-1587.98 F-NS VF-NS			CD V-1263.99 F-1263.99 VF-NS			CD V-2088.10 F-NS VF-NS		

Plate 2.

A. Treatment combination with highest green fodder yield in bajra.

B. Treatment combination with highest green fodder yield in sorghum.



A

B

Plate 2.

green fodder yield (17629.51 kg ha^{-1}) and was significantly superior to v_1 which recorded a green fodder yield at 16222.07 kg ha^{-1}. Application of the highest level of chemical fertilizers (f_2) recorded a maximum green fodder yield of 17626.14 kg ha^{-1}. Among the combinations v_2f_2 recorded the highest green fodder yield (18669.64 kg ha^{-1}) in *Sesbania rostrata*.

Green fodder yield of cowpea was significantly influenced by increasing levels of vermicompost. Fertilizer application could not significantly influence the green fodder yield. V x F interaction was also not significant. v_2 recorded the highest green fodder yield (24358.88 kg ha^{-1}) while v_1 recorded 20905.34 kg ha^{-1}. Eventhough the interaction effect V x F was not significant, the maximum green fodder yield was recorded by the v_2f_2 combination (24518.4 kg ha^{-1}).

Among the four fodder crops, fodder cowpea registered the highest green fodder yield followed by *Sesbania rostrata*. Bajra recorded the lowest green fodder yield.

4.2.2 Dry fodder yield (Table 4.5)

Dry fodder yield of bajra was significantly influenced by different levels of vermicompost though the effect of different fertilizer doses and V x F interactions were not significant. The maximum dry fodder yield

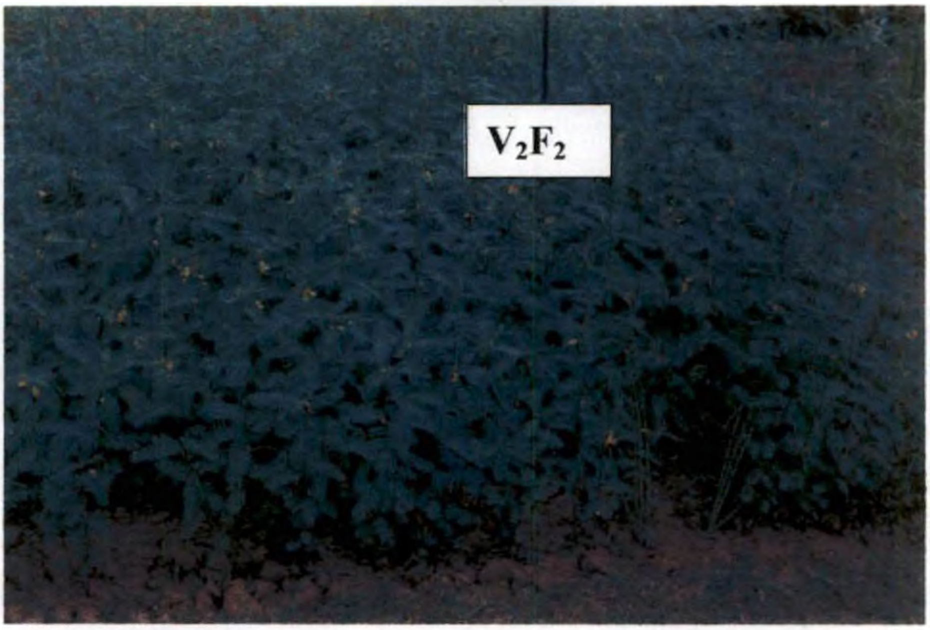
Table 4.5 Dry fodder yield (kg ha^{-1}) of fodder crops as influenced by vermicompost fertilizer combinations

	Bajra			Sorghum			*Sesbania rostrata*			Cowpea		
	v_1	v_2	F-mean	v_1	v_2	F-mean	v_1	v_2	F-mean	v_1	v_2	F-mean
f_1	1152.39	2125.58	1638.98	3756.12	3910.89	3833.50	2739.62	3035.03	2887.33	1726.44	2574.39	2150.42
f_2	1462.18	2162.94	1812.56	3759.85	5033.26	4396.50	3100.32	3867.56	3483.94	2232.42	2694.67	2463.54
V-mean	1307.28	2144.26		3757.99	4472.08		2919.97	3451.29		1979.43	2634.53	
	CD V- 634.29 F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-275.78 F-275.78 VF-NS			CD V-360.76 F-NS VF-NS		

Plate 3.

A. Treatment combination with highest green fodder yield in *Sesbania rostrata*.

B. Treatment combination with highest green fodder yield in cowpea.



A

B

Plate 3.

of 2144.26 kg ha^{-1} was recorded under the highest level of vermicompost (v_2).

In the case of sorghum, application of different levels of vermicompost and different levels of fertilizers could not record any significant influence on dry fodder yield. V x F interaction was also not significant.

In *Sesbania rostrata* application of increasing levels of vermicompost significantly increased the dry fodder yield. Fertilizer also had a favourable influence on dry fodder yield. V x F interaction was not significant. The highest dose of vermicompost (v_2) resulted in a higher dry fodder yield (3451.29 kg ha^{-1}). f_2 recorded the highest dry fodder yield (3483.94 kg ha^{-1}). Eventhough interaction effect was not significant. v_2f_2 recorded the highest dry fodder yield (3867.56 kg ha^{-1}) in *Sesbania rostrata*.

Significant difference in dry fodder yield of cowpea was observed by the application of higher dose of vermicompost. Fertilizers could not produce any significant difference in dry fodder yield of cowpea. V x F interaction was also not significant. Application of vermicompost 5 t ha^{-1} (v_2) recorded the maximum dry fodder yield (2634.53 kg ha^{-1}).

Among the four fodder crops the highest dry fodder yield was recorded by sorghum followed by *Sesbania rostrata*. Bajra recorded the lowest dry fodder yield.

4.3 Quality characters

4.3.1 Crude Protein Content (Table 4.6)

The crude protein content of bajra was significantly influenced by vermicompost at 20 DAS and at 40 DAS. At harvest, vermicompost could not produce any significant difference in crude protein content. As the vermicompost application was increased from 2.5 t ha^{-1} to 5 t ha^{-1}, a significant increase in crude protein content of the fodder was observed at 20 DAS and at 40 DAS. With the highest level of vermicompost (v_2), highest crude protein content was observed. Fertilizer doses favourably influenced the crude protein content only at 20 DAS. The highest fertilizer level recorded the maximum value for crude protein content (8.07 per cent) at this stage. V x F interaction was not significant.

Increasing levels of vermicompost significantly increased the crude protein content of sorghum at 20 DAS, 60 DAS and at harvest. The highest level of vermicompost (v_2) recorded the highest crude protein content at these stages. A significant response was obtained by the application of fertilizers on crude protein content at 20 DAS and at 60 DAS. Highest levels of fertilizer (f_2) recorded the maximum value. V x F interaction was not significant at all these stages.

Vermicompost application favourably influenced the crude protein content of *Sesbania rostrata* at 40 DAS and at harvest. At both the

Table 4.6 Crude protein content (%) of different fodder crops as influenced by vermicompost fertilizer combinations

Bajra

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F-mean	v_1	v_2	F-mean	v_1	v_2	F-mean
f_1	4.29	10.13	7.21	7.74	7.88	7.81	7.79	8.19	7.99
f_2	5.86	10.28	8.07	7.74	8.05	7.89	7.91	8.27	8.09
V-mean	5.08	10.21		7.74	7.97		7.89	8.23	
	CD V- 0.706 F-0.706 VF-NS			CD V-0.223 F-NS VF-NS			CD V-NS F-NS VF-NS		

Sorghum

	20 DAS			40 DAS			60 DAS			80 DAS			Harvest		
	v_1	V_2	F mean	V_1	V_2	F mean	V_1	V_2	F mean	V_1	V_2	F mean	V_1	V_2	F mean
f_1	8.97	10.39	9.68	6.28	7.23	6.75	8.40	9.79	9.09	4.36	4.74	4.55	4.16	5.43	4.80
f_2	10.24	10.99	10.61	6.45	7.27	6.86	9.56	10.24	9.89	4.45	5.24	4.84	4.46	5.44	4.95
V mean	9.60	10.69		6.37	7.25		8.98	10.02		4.40	4.99		4.32	5.44	
	CD V-0.73 F-0.73 VF-NS			CD V-NS F-NS VF-NS			CD V-0.733 F-0.733 VF-NS			CD V-NS F-NS VF-NS			CD V-0.854 F-NS VF-NS		

Table contd.

Sesbania rostrata

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	14.94	15.80	15.37	19.59	21.48	20.54	8.87	11.82	10.35
f_2	15.12	15.74	15.43	20.59	21.60	21.09	11.01	12.01	11.51
V mean	15.03	15.77		20.09	21.54		9.94	11.92	
	CD V-NS F-NS VF-NS			CD V-0.47 F-0.47 VF-NS			CD V-1.51 F-NS VF-NS		

Cowpea

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	16.86	17.88	17.37	16.09	19.06	17.58	11.61	11.86	11.73
f_2	17.04	17.19	17.12	16.58	19.56	18.07	11.80	12.08	11.94
V mean	16.95	17.54		16.33	19.31		11.70	11.97	
	CD V-NS F-NS VF-NS			CD V-1.78 F-NS VF-NS			CD V-NS F-NS VF-NS		

stages v_2 registered the maximum crude protein content. Fertilizer levels significantly influenced the crude protein content only at 40 DAS. f_2 recorded the maximum value and was significantly superior to f_1. V x F interaction was not significant.

Different levels of vermicompost produced a significant difference in crude protein content of cowpea only at 40 DAS. Highest dose of vermicompost (v_2) recorded the maximum crude protein content at this stage (19.31 per cent). Fertilizers and V x F interaction could not favourably influence the crude protein content at any stage of the crop.

4.3.2 Crude fibre content (Table 4.7)

Crude fibre content of bajra was significantly influenced by vermicompost. Fertilizer levels also showed a significant influence on crude fibre content. V x F interaction was not significant. As the vermicompost level was increased from 2.5 t ha^{-1} to 5 t ha^{-1} a significant reduction in crude fibre content was noticed. v_2 recorded the lowest crude fibre content (26.6 per cent) in bajra. Fertilizers also showed a similar trend on crude fibre content. The lowest dose of fertilizer recorded the highest crude fibre content (26.97 per cent).

In the case of sorghum increasing levels of vermicompost significantly influenced the crude fibre content. Fertilizers also favourably influenced the crude fibre content. V x F interaction was also

Table 4.7 Crude fibre content (%) of fodder crops as influenced by vermicompost fertilizer combination

	Bajra			Sorghum			*Sesbania rostrata*			Cowpea		
	v_1	v_2	F-mean	v_1	v_2	F-mean	v_1	v_2	F-mean	v_1	v_2	F-mean
f_1	27.26	26.67	26.97	29.12	27.84	28.48	27.29	25.67	26.48	25.48	24.56	25.02
f_2	26.99	26.54	26.76	28.29	27.62	27.95	26.46	25.46	25.96	25.06	23.57	24.31
Vmean	27.12	26.60		28.70	27.73		26.87	25.56		25.27	24.07	
	CD V- 0.12 F-0.12 VF-NS			CD V-0.22 F-0.22 VF-0.31			CD V-0.17 F-0.17 VF-0.24			CD V-0.095 F-0.095 VF-0.134		

significant. Increasing levels of vermicompost significantly decreased the crude fibre content. v_2 recorded the lowest crude fibre content (27.73 per cent) in sorghum. A similar trend on crude fibre content was shown by fertilizers. f_2 recorded the lowest crude fibre content (27.95 per cent) in sorghum. A significant interaction was observed between vermicompost and fertilizers with respect to crude fibre content. When the highest dose of vermicompost (v_2) was combined with the highest dose of fertilizer (f_2), it resulted in the lowest crude fibre content (27.62 per cent). This was on par with v_2f_1 with a crude fibre content of 27.84 per cent.

Increasing levels of vermicompost significantly decreased the crude fibre content of *Sesbania rostrata* and cowpea. Different fertilizer levels also showed significant response in crude fibre content. Significant interaction was observed between vermicompost and fertilizer with respect to crude fibre content in both the crops. The highest levels of both vermicompost (v_2) and fertilizer (f_2) recorded the lowest crude fibre content. Among the combinations, v_2f_2 recorded the lowest crude fibre content in *Sesbania rostrata* (25.46 per cent) and cowpea (23.57 per cent). In the case of *Sesbania rostrata,* v_2f_2 was on par with v_2f_1 but in cowpea, v_2f_2 was significantly superior to all other treatments.

Among the four fodder crops, the lowest crude fibre content was recorded by cowpea followed by *Sesbania rostrata*. Highest crude fibre content was recorded by sorghum.

4.4 Plant analysis

4.4.1 Content of nitrogen in fodder (Table 4.8)

In the case of bajra, application of increasing levels of vermicompost and chemical fertilizers was found to have a significant effect on the N content of fodder at 20 DAS. The highest N content (1.645 per cent) was recorded by the treatment receiving highest levels of vermicompost and chemical fertilizers *viz.*, v_2f_2 which was on par with the treatment v_1f_1 (1.621 per cent). Different levels of nutrients could not influence the N content of fodder at 40 DAS and at harvest.

The N content of fodder was significantly influenced by various treatments at 20 DAS and at 60 DAS in sorghum. Significant difference in N content was observed between combinations of different levels of vermicompost and chemical fertilizers. It was observed that application of vermicompost 5 t ha^{-1} and 100 per cent POP recorded the highest N content at both the stages *viz.*, 20 DAS and 60 DAS (1.76 and 1.64 per cent) respectively. The treatment receiving vermicompost 2.5 t ha^{-1} and 50 per cent POP (v_1f_1) was significantly inferior to all other treatments

Table 4.8 Nitrogen content (%) of different fodder crops as influenced by vermicompost fertilizer combinations

Bajra

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	0.688	1.238	1.247
v_1f_2	0.938	1.238	1.266
v_2f_1	1.621	1.261	1.309
v_2f_2	1.645	1.287	1.323
F	93.83**	NS	NS
CD	0.160	--	--

Sorghum

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
v_1f_1	1.44	1.01	1.34	0.70	0.67
v_1f_2	1.64	1.03	1.53	0.71	0.71
v_2f_1	1.66	1.16	1.57	0.77	0.85
v_2f_2	1.76	1.16	1.64	0.84	0.87
F	6.93*	NS	5.86*	NS	3.46
CD	0.17	--	0.17	--	--

Sesbania rostrata

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	2.39	3.13	1.42
v_1f_2	2.42	3.29	1.76
v_2f_1	2.53	3.44	1.89
v_2f_2	2.54	3.46	1.92
F	NS	20.03**	4.62*
CD	--	0.11	0.342

Cowpea

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	2.69	2.58	1.86
v_1f_2	2.73	2.65	1.89
v_2f_1	2.86	3.05	1.90
v_2f_2	2.75	3.13	1.93
F	NS	4.91*	NS
CD	--	0.40	--

at 20 DAS and 60 DAS (1.44 and 1.34 per cent) respectively. There was no significant difference among the various treatments at 40 DAS at 80 DAS and at harvest.

In *Sesbania rostrata* N content of plant increased upto 40 DAS and then decreased. Application of different levels of nutrients was found to have a significant effect on the N content of fodder at 40 DAS and at harvest. The maximum N content (3.46 and 1.92 per cent respectively) was recorded with the application of vermicompost 5 t ha^{-1} and 100 per cent POP (v_2f_2) recommendation at both the stages. N content of fodder was not significantly influenced by various treatments at 20 DAS.

In cowpea, the N content of fodder was not significantly influenced by various treatments at 20 DAS and at harvest and was significant only at 40 DAS. The highest N content (3.13 per cent) was recorded by the treatment receiving the highest levels of vermicompost and chemical fertilizers at 40 DAS. The lowest N content (2.58 per cent) was recorded by the lowest level of vermicompost and chemical fertilizers, which was on par with the treatment receiving vermicompost 2.5 t ha^{-1} and 100 per cent POP (2.65 per cent).

4.4.2 Content of phosphorus in fodder (Table 4.9)

The data revealed that in bajra, phosphorus content of fodder was significantly influenced by various combinations of vermicompost and chemical fertilizers at all the stages of growth. Increase in nutrient levels registered a significant progressive increase in phosphorus content of fodder. Application of vermicompost 5 t ha^{-1} and 100 per cent POP (v_2f_2) resulted in higher phosphorus content (0.231, 0.108 and 0.203 per cent respectively) at 20 DAS, 40 DAS and at harvest. Lowest phosphorus content (0.137, 0.05 and 0.053 per cent respectively) was observed with the application of vermicompost 2.5 t ha^{-1} and 50 percent POP (v_1f_1) at all the stages.

In sorghum, significant response on phosphorus content of fodder was obtained by the application of various levels of vermicompost and chemical fertilizers at all the stages except at 20 DAS. Vermicompost 5 t ha^{-1} and 100 per cent POP recorded the highest phosphorus content at all the stages which was on par with the treatment receiving vermicompost 5 t ha^{-1} and 50 per cent POP at 40 DAS and 80 DAS. At 60 DAS all the other treatments except v_2f_2 were on par with each other. During the last stage of observation it was seen that the treatment receiving vermicompost 5 t ha^{-1} and 50 percent POP and vermicompost 2.5 t ha^{-1} and 100 per cent POP were on par.

Table 4.9 Phosphorus content (%) of different fodder crops as influenced by vermicompost fertilizer combinations

Bajra

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	0.137	0.050	0.053
v_1f_2	0.145	0.090	0.055
v_2f_1	0.205	0.103	0.105
v_2f_2	0.231	0.108	0.203
F	81.04**	9.59**	283.31**
CD	0.016	0.03	0.013

Sorghum

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
v_1f_1	0.140	0.058	0.050	0.048	0.055
v_1f_2	0.148	0.063	0.055	0.053	0.125
v_2f_1	0.250	0.105	0.055	0.100	0.138
v_2f_2	0.321	0.118	0.153	0.108	0.258
F	NS	40.07**	42.12**	14.92**	45.40**
CD	--	0.015	0.025	0.026	0.039

Sesbania rostrata

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	0.085	0.080	0.198
v_1f_2	0.148	0.100	0.228
v_2f_1	0.208	0.103	0.231
v_2f_2	0.254	0.139	0.252
F	21.35**	30.07**	NS
CD	0.051	0.014	--

Cowpea

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	0.042	0.053	0.209
v_1f_2	0.071	0.074	0.213
v_2f_1	0.075	0.094	0.273
v_2f_2	0.115	0.153	0.253
F	13.63**	149.19**	6.41*
CD	0.027	0.012	0.039

In the case of *Sesbania rostrata* phosphorus content of fodder was significantly influenced by different nutrient levels at 20 DAS and 40 DAS. No significant response was observed at the third stage. At 20 DAS and at 40 DAS v_2f_2 recorded the maximum phosphorus content (0.254 and 0.139 per cent respectively) and the treatment receiving vermicompost 2.5 t ha^{-1} and 50 per cent POP (v_1f_1) recorded the minimum phosphorus content (0.085 and 0.08 per cent respectively) which was significantly less than all other treatments.

The different nutrient levels produced a significant effect on phosphorus content of cowpea plants at all the stages. Phosphorus content increased with increasing levels of nutrients. Highest level of vermicompost and chemical fertilizers produced the maximum phosphorus content at all the stages of growth *viz.*, 20 DAS, 40 DAS and at harvest (0.115, 0.153 and 0.253 per cent) respectively.

4.4.3 Content of potassium in fodder (Table 4.10)

In bajra, the data revealed that the potassium content of fodder was significantly influenced by different levels of vermicompost and chemical fertilizers at 20 DAS and 40 DAS. There was no significant difference between various treatments at harvest. Increasing level of nutrients increased the potassium content of fodder and the treatment receiving vermicompost 5 t ha^{-1} and 100 per cent POP (v_2f_2) recorded

Table 4.10 Potassium content (%) of different fodder crops as influenced by vermicompost fertilizer combinations

Bajra

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	1.71	1.64	2.06
v_1f_2	2.41	2.03	2.23
v_2f_1	2.53	2.04	2.24
v_2f_2	2.83	2.83	2.31
F	83.55**	109.35**	NS
CD	0.165	0.154	--

Sorghum

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
v_1f_1	1.19	1.53	1.25	1.17	0.81
v_1f_2	1.25	1.58	1.31	1.24	0.88
v_2f_1	1.63	1.63	1.48	1.32	1.04
v_2F_2	1.65	1.75	2.43	1.43	1.09
F	107.82**	8.44**	84.02**	9.83**	15.65**
CD	0.08	0.104	0.191	0.113	0.108

Sesbania rostrata

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	3.00	1.92	2.19
v_1f_2	3.06	2.09	2.22
v_2f_1	3.06	2.11	2.29
v_2f_2	3.18	2.11	2.39
F	NS	4.53*	NS
CD	--	0.141	--

Cowpea

Treatments	20 DAS	40 DAS	Harvest
v_1f_1	2.58	1.79	2.83
v_1f_2	2.60	2.32	2.95
v_2f_1	2.89	2.42	3.15
v_2f_2	3.72	2.48	4.58
F	45.62**	18.86**	180.45**
CD	0.252	0.232	0.193

the maximum potassium content at 20 DAS and 40 DAS (2.83 and 2.83 per cent respectively) and this was significantly higher than all other treatments.

In the case of sorghum, application of vermicompost and chemical fertilizers in various combinations had significant influence on the potassium content of fodder at all the five stages studied. The treatment receiving vermicompost 5 t ha^{-1} and 100 per cent POP recorded the maximum potassium content at all stages of growth *viz*., 20, 40, 60, 80 DAS and at harvest (1.65, 1.75, 2.43, 1.43 and 1.09 per cent respectively).

The potassium content of fodder was not significantly influenced by different levels of nutrients at 20 DAS and at harvest in *Sesbania rostrata*. At 40 DAS all the treatments except the treatment receiving vermicompost 2.5 t ha^{-1} and 50 percent POP (v_1f_1) were on par. Among the various treatments, v_1f_1 recorded the lowest potassium content (1.92 per cent) and was significantly inferior to all other treatments.

In cowpea, there was significant difference in potassium content of fodder during all stages of growth *viz*., 20 DAS, 40 DAS and at harvest. With the application of different levels of vermicompost and chemical fertilizers, maximum potassium content (3.72, 2.48 and 4.58 per cent respectively) was recorded with the application of vermicompost 5 t ha^{-1} and 100 per cent POP, while the lowest potassium content (2.58, 1.79 and 2.83 percent respectively) was produced with the application of v_1f_1.

4.5 Uptake of nutrients

4.5.1 Nitrogen uptake (Table 4.11)

In bajra application of increasing levels of vermicompost significantly increased the uptake of nitrogen only at the time of harvest. The highest dose of vermicompost (5 t ha^{-1}) recorded the highest uptake of nitrogen at this stage (28.04 kg ha^{-1}). Different levels of fertilizers and V x F interactions were not significant.

In the case of sorghum, higher levels of vermicompost produced significant difference in nitrogen uptake at 40 DAS and at harvest. Application of vermicompost 5 t ha^{-1} (v_2) resulted in highest uptake at these stages (3.05 and 38.59 kg ha^{-1} respectively). Fertilizer application could not produce any significant change in nitrogen uptake of sorghum. V x F interaction was also not significant.

In *Sesbania rostrata* various levels of vermicompost influenced the nitrogen uptake only at the time of harvest. Significant increase in uptake of nitrogen was noticed at the time of harvest. Highest nitrogen uptake (65.31 kg ha^{-1}) was noticed with the application of vermicompost 5 t ha^{-1}. Different levels of fertilizers also produced significant change

Table 4.11 Nitrogen uptake (kg ha^{-1}) of different fodder crops as influenced by vermicompost fertilizer combination

Bajra

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.18	0.34	0.26	2.51	3.48	2.99	14.43	27.58	21.00
f_2	0.29	0.46	0.38	3.02	4.43	3.73	18.43	28.49	23.47
V mean	0.23	0.40		2.77	3.96		16.43	28.04	
	CD V-NS F-NS VF-NS			CD V-1.78 F-NS VF-NS			CD V-7.53 F-NS VF-NS		

Sorghum

	20 DAS			40 DAS			60 DAS			80 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.417	0.493	0.455	1.55	3.02	2.28	7.94	12.46	10.2	11.52	16.95	14.23	24.85	33.26	29.05
f_2	0.486	0.615	0.550	1.99	3.08	2.54	14.68	15.78	15.23	13.08	17.55	15.31	26.85	43.93	35.39
V mean	0.451	0.554		1.77	3.05		11.31	14.12		12.29	17.25		25.85	38.59	
	CD V-NS F-NS VF-NS			CD V-0.86 F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-8.09 F-NS VF-NS		

Table contd.

Sesbania rostrata

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	1.47	1.69	1.58	8.91	15.87	12.39	38.94	57.38	48.16
f_2	1.68	1.74	1.71	15.02	20.46	17.74	54.52	73.24	63.88
V mean	1.58	1.72		11.96	18.17		46.73	65.31	
	CD V-NS F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-6.51 F-6.51 VF-NS		

Cowpea

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	2.99	3.07	3.03	16.89	18.98	17.93	31.92	48.73	40.32
f_2	3.06	3.86	3.46	18.71	20.78	19.74	42.14	52.02	47.08
V mean	3.03	3.47		17.80	19.88		37.03	50.37	
	CD V-NS F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-6.212 F-6.212 VF-NS		

in nitrogen uptake at the time of harvest. Application of f_2 (100 per cent POP) recorded the highest nitrogen uptake (63.88 kg ha^{-1}). V x F interaction was not significant.

Nitrogen uptake of cowpea was favourably influenced by the application of different levels of vermicompost only at the time of harvest. Highest dose of vermicompost (5 t ha^{-1}) recorded the highest nitrogen uptake (50.37 kg ha^{-1}) at this stage. Different levels of fertilizer also significantly influenced the nitrogen uptake at harvest stage. The highest level of 100 per cent POP (f_2) produced the highest nitrogen uptake (47.08 kg ha^{-1}). V x F interaction was not significant.

Among the fodder crops, highest N uptake at the time of harvest was recorded by *Sesbania rostrata* followed by cowpea. Bajra recorded the lowest nitrogen uptake.

4.5.2 Phosphorus uptake (Table 4.12)

Higher levels of vermicompost significantly increased the phosphorus uptake of bajra only at the time of harvest. Application of vermicompost (5 t ha^{-1}) recorded the maximum phosphorus uptake (1.95 kg ha^{-1}) at this stage. Different fertilizer levels also influenced the phosphorus uptake significantly at harvest. The highest level of fertilizer (f_2) recorded the highest phosphorus uptake (1.933 kg ha^{-1}). V x F interaction was significant at the time of harvest. The highest

Table 4.12 Phosphorus uptake (kg ha^{-1}) of different fodder crops as influenced by vermicompost fertilizer combinations

Bajra

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.035	0.049	0.042	0.145	0.202	0.172	0.775	1.221	0.998
f_2	0.044	0.057	0.051	0.199	0.374	0.288	1.194	2.673	1.933
V mean	0.039	0.053		0.174	0.286		0.984	1.950	
	CD V-NS F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-0.450 F-0.450 VF-0.631		

Sorghum

	20 DAS			40 DAS			60 DAS			80 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.040	0.060	0.050	0.110	0.280	0.200	0.300	0.480	0.390	0.900	1.620	1.260	2.780	5.230	4.010
f_2	0.060	0.070	0.070	0.170	0.380	0.280	0.440	0.760	0.600	0.950	2.530	1.740	4.930	9.660	7.290
V mean	0.050	0.070		0.140	0.330		0.370	0.62		0.920	2.070		3.860	7.450	
	CD V-NS F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-0.20 F-0.20 VF-NS			CD V-0.55 F-NS VF-NS			CD V-0.176 F-0.176 VF-NS		

Table contd.

Sesbania rostrata

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.047	0.124	0.086	0.472	0.492	0.482	5.408	7.105	6.256
f_2	0.094	0.157	0.126	0.478	0.656	0.567	6.908	9.760	8.334
V mean	0.075	0.14		0.475	0.574		6.158	8.433	
	CD V-0.033 F-0.033 VF-NS			CD V-NS F-NS VF-NS			CD V-1.795 F-1.795 VF-NS		

Cowpea

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.051	0.112	0.082	0.284	0.464	0.374	3.621	6.851	5.231
f_2	0.077	0.132	0.104	0.422	1.022	0.722	4.770	7.032	5.891
V mean	0.064	0.122		0.353	0.743		4.201	6.941	
	CD V-0.033 F-NS VF-NS			CD V-0.24 F-0.24 VF-NS			CD V-1.30 F-NS VF-NS		

phosphorus uptake ($2.673\ kg\ ha^{-1}$) was obtained with the application of highest level of vermicompost and fertilizer (v_2f_2) and it was significantly superior to all other treatments.

In the case of sorghum, higher levels of vermicompost significantly influenced the phosphorus uptake at 60 DAS, 80 DAS and at harvest. Maximum uptake of phosphorus was recorded with the application of vermicompost 5 t ha^{-1} at these stages (0.62, 2.07 and 7.45 kg ha^{-1} respectively). Different levels of fertilizer favourably influenced the phosphorus uptake at 60 DAS and at harvest. Application of f_2 (100 per cent POP) recorded the highest phosphorus uptake at these stages (0.60 and 7.29 kg ha^{-1} respectively). V x F interaction was not significant at all stages studied.

In *Sesbania rostrata,* application of different levels of vermicompost favourably influenced the phosphorus uptake at 20 DAS and at harvest. The highest phosphorus uptake was recorded with the application of vermicompost 5 t ha^{-1} at these stages (0.141 and 8.433 kg ha^{-1} respectively). Different levels of fertilizer also significantly influenced the phosphorus uptake of these stages. f_2 recorded the maximum phosphorus uptake at these stages (0.126 and 8.334 kg ha^{-1} respectively). V x F interaction was not significant.

Cowpea plants showed a significant increase in phosphorus uptake at all the stages with the application of higher levels of vermicompost.

The highest dose of vermicompost recorded the highest phosphorus uptake at these stages *viz.*, 20 DAS, 40 DAS and at harvest (0.122, 0.743 and 6.94 kg ha^{-1} respectively). Different fertilizer levels favourably influenced the phosphorus uptake only at 40 DAS. Highest fertilizer level recorded the maximum phosphorus uptake (0.722 kg ha^{-1}) at this stage. V x F interaction was not significant at all the three stages.

At the time of harvest, highest phosphorus uptake was recorded by *Sesbania rostrata* followed by sorghum and lowest phosphorus uptake was registered by bajra.

4.5.3 Potassium uptake (Table 4.13)

In bajra application of different levels of vermicompost could not produce any significant difference in potassium uptake. Increasing levels of fertilizers favourably influenced the potassium uptake at the time of harvest and the highest level of fertilizer (f_2) recorded the highest potassium uptake (45.73 kg ha^{-1}). V x F interaction was also not significant at all stages.

In the case of sorghum, increasing levels of vermicompost significantly influenced the potassium uptake at 40 DAS, 80 DAS and at harvest. Highest dose of vermicompost (v_2) record the maximum uptake of potassium at these stages (4.46, 30.39 and 48.15 kg ha^{-1} respectively).

Table 4.13 Potassium uptake (kg ha^{-1}) of different fodder crops as influenced by vermicompost fertilizer combinations

Bajra

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.36	0.73	0.55	4.62	5.66	5.14	25.69	33.81	29.75
f_2	0.66	0.79	0.73	4.75	7.00	5.88	43.08	48.38	45.73
V mean	0.51	0.76		4.68	6.33		34.39	41.10	
	CD V-NS F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-NS F-13.89 VF-NS		

Sorghum

	20 DAS			40 DAS			60 DAS			80 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	0.314	0.500	0.407	2.59	4.21	3.40	10.34	13.28	11.81	18.79	31.18	24.99	30.41	41.11	35.76
f_2	0.501	0.503	0.502	2.85	4.71	3.77	12.91	14.39	13.65	20.99	29.59	25.29	32.75	55.20	43.98
V mean	0.408	0.501		2.72	4.46		11.62	13.83		19.89	30.39		31.58	48.15	
	CD V-NS F-NS VF-NS			CD V-1.26 F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-7.99 F-NS VF-NS			CD V-9.00 F-NS-NS VF-NS		

Table contd.

Sesbania rostrata

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	1.80	1.84	1.82	6.48	12.56	9.52	65.36	69.64	67.49
f_2	1.81	1.96	1.89	10.42	13.80	12.11	68.74	84.35	76.54
V mean	1.81	1.90		8.45	13.18		67.05	76.99	
	CD V-NS F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-7.73 F-7.73 VF-NS		

Cowpea

	20 DAS			40 DAS			Harvest		
	v_1	v_2	F mean	v_1	v_2	F mean	v_1	v_2	F mean
f_1	2.61	3.67	3.14	10.13	13.15	11.64	50.72	72.63	61.67
f_2	3.09	6.12	4.61	12.85	16.34	14.59	70.61	123.61	97.11
V mean	2.85	4.90		11.49	14.75		60.67	98.12	
	CD V-1.652 F-NS VF-NS			CD V-NS F-NS VF-NS			CD V-14.54. F-14.54 VF-NS		

Different levels of fertilizer did not influence the potassium uptake of sorghum. V x F interaction was also not significant at all stages.

Sesbania rostrata plants recorded significantly higher uptake of potassium (76.99 kg ha^{-1}) with the application of higher dose of vermicompost (v_2) only at the time of harvest. Different fertilizer levels also favourably influenced the potassium uptake only at the time of harvest. Application of highest level of fertilizer (f_2) recorded the maximum uptake (76.54 kg ha^{-1}). V x F interaction was not significant at all stages.

In cowpea, different levels of vermicompost significantly influenced the uptake of potassium at 20 DAS and at harvest. The highest level of vermicompost (v_2) recorded the highest potassium uptake at both the stages (4.90 and 98.12 kg ha^{-1} respectively). Highest dose of fertilizer (f_2) significantly increased the uptake of potassium in cowpea at the time of harvest. V x F interaction was not significant at all stages.

Among the four fodder crops, cowpea recorded the highest potassium uptake followed by *Sesbania rostrata*. Bajra recorded the lowest potassium uptake.

4.6 Soil analysis

4.6.1 Physical properties of soil

4.6.1.1 Bulk density of soil (Table 4.14)

Bulk density of soil after the experiment was significantly influenced by different fodder crops. Bulk density was highest in plots grown with bajra (1.309). Sorghum plots recorded a bulk density of 1.307. Leguminous fodders reduced the bulk density of soil than cereal fodders and the least bulk density was recorded with *Sesbania rostrata* (1.300). Cowpea plots registered a bulk density of 1.304.

It was seen that bulk density of soil decreased significantly with increasing levels of vermicompost and chemical fertilizers and the lowest bulk density (1.294) was recorded with the application of vermicompost 5 t ha^{-1} and 100 per cent POP (v_2f_2) and bulk density was maximum (1.321) with the application of vermicompost 2.5 t ha^{-1} and 50 per cent POP (v_1f_1).

A significant interaction was noticed between fodder crops and different nutrient levels. Bulk density of soil was highest (1.329) with the application of vermicompost 2.5 t ha^{-1} and 50 per cent POP (v_1f_1) in bajra followed by the application of same level of nutrients in sorghum (1.324). Lowest bulk density (1.292) was recorded with v_2f_2 in *Sesbania*

Table 4.14 Effect of fodder crops and nutrient levels on bulk density of soil (gcc^{-1})

Treatments	v_1f_1	v_1f_2	v_2f_1	v_2f_2	Crop mean
Bajra	1.329	1.313	1.299	1.295	1.309
Sorghum	1.324	1.311	1.299	1.294	1.307
Sesbania rostrata	1.311	1.301	1.296	1.292	1.300
Cowpea	1.319	1.307	1.297	1.293	1.304
VF mean	1.321	1.308	1.298	1.294	

CD (Crops) – 0.001

CD (VF) – 0.001

CD (Crops x VF) – 0.003

rostrata which was on par with the treatments receiving same levels of vermicompost and chemical fertilizers in cowpea, sorghum and bajra.

4.6.1.2 Water holding capacity (Table 4.15)

Different fodder crops produced significant variation in the water holding capacity of the soil after the experiment. Water holding capacity was increased with the cultivation of leguminous fodder crops than with the cultivation of cereal fodder crops. Sesbania plots recorded the highest water holding capacity (26.23 per cent) and water holding capacity was lowest (26.05 per cent) in plots grown with bajra.

It is evident from the table that the water holding capacity increased with increasing levels of nutrients. Maximum water holding capacity (26.46 per cent) was noticed with v_2f_2 and minimum (25.92 per cent) with the application of v_1f_1.

In the case of fodder crops x nutrient levels interaction, the maximum water holding capacity (26.63 per cent) was recorded from sesbania plots receiving the treatments v_2f_2 followed by cowpea plots receiving the same level of nutrients. Both the treatments were on par with each other. Water holding capacity was lowest (25.88 per cent) in bajra plots receiving vermicompost 2.5 t ha^{-1} and 50 per cent POP (v_1f_1) which was on par with the water holding capacity of sorghum and cowpea plots receiving the same level of nutrient *ie.*, v_1f_1.

Table 4.15 Effect of fodder crops and nutrient levels on water holding capacity of soil (%)

Treatments	v_1f_1	v_1f_2	v_2f_1	v_2f_2	Crop mean
Bajra	25.88	25.96	26.08	26.26	26.05
Sorghum	25.92	26.00	26.19	26.44	26.14
Sesbania rostrata	25.95	26.05	26.31	26.63	26.23
Cowpea	25.93	26.03	26.27	26.53	26.19
VF mean	25.92	26.01	26.21	26.46	

CD (Crops) – 0.02

CD (VF) – 0.03

CD (Crops x VF) – 0.06

Table 4.16 Effect of fodder crops and nutrient levels on organic carbon content of soil (%)

Treatments	v_1f_1	v_1f_2	v_2f_1	v_2f_2	Crop mean
Bajra	1.04	1.20	1.27	1.37	1.22
Sorghum	1.14	1.25	1.28	1.39	1.27
Sesbania rostrata	1.25	1.26	1.31	1.37	1.29
Cowpea	1.22	1.24	1.33	1.49	1.32
VF mean	1.16	1.24	1.30	1.40	

CD (Crops) – NS

CD (VF) – 0.124

CD (Crops x VF) – NS

4.6.2 Chemical properties of soil

4.6.2.1 Organic carbon content of soil (Table 4.16)

Organic carbon content of the soil after the experiment was not influenced by different fodder crops.

Application of different levels of nutrients significantly influenced the organic carbon content of soil. Increasing levels of vermicompost and chemical fertilizers increased the organic carbon content of the soil and was more (1.40 per cent) on applying vermicompost 5 t ha^{-1} and 100 per cent POP which was on par with vermicompost 5 t ha^{-1} and 50 per cent POP (1.3 per cent).

No significant interaction was observed between different nutrient levels and fodder crops on organic carbon content of soil.

4.6.2.2 Available nitrogen status of soil (Table 4.17)

Available nitrogen in soil after the experiment was significantly influenced by the cultivation of cereal and leguminous fodder crops. Considerable improvement in nitrogen status was noticed after the cultivation of leguminous fodder crops. The plots where *Sesbania rostrata* were grown recorded the highest nitrogen content (315.61 kg ha^{-1}). This was closely followed by cowpea (299.82 kg ha^{-1}) which was

Table 4.17 Effect of fodder crops and nutrient levels on available nitrogen status of soil (kg ha^{-1})

Treatments	v_1f_1	v_1f_2	v_2f_1	v_2f_2	Crop mean
Bajra	269.02	288.03	289.01	297.10	285.79
Sorghum	267.36	275.79	283.76	295.33	280.56
Sesbania rostrata	304.81	311.92	318.91	326.81	315.61
Cowpea	286.31	293.35	307.49	312.13	299.82
VF mean	281.88	292.27	299.79	307.84	

CD (Crops) – 15.09

CD (VF) – 9.77

CD (Crops x VF) – NS

on par with bajra and sorghum (285.79 kg ha^{-1} and 280.56 kg ha^{-1} respectively).

Application of vermicompost 5 t ha^{-1} and 100 per cent POP and vermicompost 5 t ha^{-1} and 50 per cent POP which were on par with each other increased the available nitrogen status of soil. Vermicompost 2.5 t ha^{-1} and 50 per cent POP recorded the lowest nitrogen content (281.88 kg ha^{-1}).

Fodder crops x nutrient levels interaction did not significantly influence the available nitrogen in soil.

4.6.2.3 Available phosphorus status of soil (Table 4.18)

Cultivation of cereal and leguminous fodder crops significantly influenced the available phosphorus content of soil. The highest available soil phosphorus after the experiment was recorded with cowpea (30.36 kg ha^{-1}). Available soil phosphorus was lowest in plots grown with *Sesbania rostrata* (26.66 kg ha^{-1}) which was on par with sorghum (26.74 kg ha^{-1}).

Increasing levels of vermicompost and chemical fertilizers increased the available phosphorus content in soil. Phosphorus content was maximum when 5 t ha^{-1} of vermicompost and 100 per cent POP recommendation was applied (32.71 kg ha^{-1}). Application of lowest level

Table 4.18 Effect of fodder crops and nutrient levels on available phosphorus content of soil (kg ha^{-1})

Treatments	v_1f_1	v_1f_2	v_2f_1	v_2f_2	Crop mean
Bajra	25.93	26.58	26.95	34.44	28.47
Sorghum	22.32	26.54	28.66	29.45	26.74
Sesbania rostrata	22.83	23.42	28.29	32.11	26.66
Cowpea	24.99	29.80	31.83	34.83	30.36
VF mean	24.02	26.59	28.93	32.71	

CD (Crops) – 0.69

CD (VF) – 0.67

CD (Crops x VF) – 1.34

of vermicompost and chemical fertilizers recorded the lowest available soil phosphorus content of 24.02 kg ha^{-1}.

Significant interaction was noticed with fodder crops x nutrients levels. Available soil phosphorus status was maximum with the application of vermicompost 5 t ha^{-1} and 100 per cent POP in cowpea (34.83 kg ha^{-1}) which was on par with the application of same level of nutrients in bajra. Application of vermicompost 2.5 t ha^{-1} and 50 per cent POP (v_1f_1) in sorghum recorded the lowest phosphorus content in soil (22.32 kg ha^{-1}) which was on par with same level of nutrients in *Sesbania rostrata*.

4.6.2.4 Available potassium status of soil (Table 4.19)

It was observed that fodder cropping significantly influenced the potassium content of soil. Higher potassium content (206.36 kg ha^{-1}) was recorded on plots where bajra was grown and cowpea plots recorded the lowest potassium content (186.54 kg ha^{-1}).

Different levels of nutrient also caused significant difference in the available potassium status of soil. The highest level of nutrients recorded the maximum potassium content (233.41 kg ha^{-1}) in soil and the minimum content (170.87 kg ha^{-1}) was recorded with the application of vermicompost 2.5 t ha^{-1} and 50 per cent POP (v_1f_1).

Table 4.19 Effect of fodder crops and nutrient levels on available potassium status of soil (kg ha^{-1})

Treatments	v_1f_1	v_1f_2	v_2f_1	v_2f_2	Crop mean
Bajra	166.03	185.68	223.10	250.65	206.36
Sorghum	164.99	186.77	214.29	231.79	199.46
Sesbania rostrata	177.38	184.79	207.55	245.35	203.77
Cowpea	175.08	182.57	182.67	205.84	186.54
VF mean	170.87	184.95	206.90	233.41	

CD (Crops) – 1.66

CD (VF) – 1.85

CD (Crops x VF) – 3.69

Nutrient levels x fodder crops interaction significantly influenced the available soil potassium status after the experiment. Increasing levels of nutrients increased the soil potassium content in both cereal and leguminous fodder crops but the potassium content was markedly high (250.65 kg ha^{-1}) in bajra plots receiving vermicompost 5 t ha^{-1} and 100 per cent POP (v_2f_2) followed by the same level of nutrients in *Sesbania rostrata* (245.35 kg ha^{-1}). In sorghum also application of vermicompost 5 t ha^{-1} and 100 per cent POP significantly increased the available potassium in soil (231.79 kg ha^{-1}). Application of vermicompost 2.5 t ha^{-1} and 50 per cent POP produced only a slight increase in the soil potassium content compared to initial potassium status of soil in sorghum (164.99 kg ha^{-1}) which was on par with same level of nutrients in bajra (166.03 kg ha^{-1}).

4.7 Economics (Table 4.20)

The data revealed that among the fodder crops highest benefit : cost ratio was recorded with cultivation of fodder cowpea (2.31) followed by *Sesbania rostrata* (1.38). Lowest benefit cost ratio was recorded by bajra (0.68). Among the various nutrient levels v_1f_2 (vermicompost 2.5 t ha^{-1} and 100 per cent POP) recorded the highest benefit : cost ratio of 1.51. The lowest benefit cost ratio was recorded by

Table 4.20 Benefit : Cost ratio

Treatments	v_1f_1	v_1f_2	v_2f_1	v_2f_2	Crop mean
Bajra	0.58	0.80	0.65	0.68	0.68
Sorghum	1.07	1.11	0.90	1.01	1.02
Sesbania rostrata	1.92	1.92	1.49	1.62	1.38
Cowpea	2.45	2.50	2.17	2.13	2.31
VF mean	1.51	1.58	1.30	1.36	

the treatment v_2f_1 (1.30). Application of vermicompost 2.5 t ha^{-1} and 100 per cent POP in cowpea recorded the highest benefit cost ratio (2.50).

DISCUSSION

5. DISCUSSION

The present study was envisaged to assess the effect of varying levels of nutrients on the production potential and quality of cereal and leguminous fodder crops raised in summer rice fallows. The changes in physico-chemical properties of soil due to fodder cropping and economics of fodder production in summer rice fallows were also studied.

The data collected on various growth characters, yield, quality characters, nutrient uptake, soil nutrient status, soil physical properties and benefit : cost ratio were analysed statistically and the results are discussed in this chapter.

5.1 Growth characters

Growth characters of both cereal and leguminous fodder crops were significantly influenced by the integrated application of vermicompost and chemical fertilizers at various levels.

Increasing levels of chemical fertilizers and vermicompost significantly increased the plant height, leaf area index and leaf stem ratio of bajra at the time of harvest. The highest value for plant height (127.7 cm), LAI (1.505) and leaf stem ratio (0.83) at harvest were recorded for the treatment receiving vermicompost 5 t ha^{-1} and 100 per cent POP recommendation (v_2f_2) in this crop. In the case of sorghum different nutrient levels significantly influenced the plant height and leaf stem ratio at 40 DAS and at harvest. LAI increased significantly only at 60 DAS. The treatment with highest level of vermicompost and chemical fertilizer recorded the maximum value for plant height at 40 DAS and at harvest (78.03 and 190.03 cm respectively), LAI at 60 DAS (1.565) and leaf stem ratio at 40 DAS and at harvest (3.06 and 0.97 respectively).

In *Sesbania rostrata* the results indicated that the plant height at 40 DAS and at harvest, LAI at 20 DAS and at harvest and leaf stem ratio at harvest were significantly influenced by the application at different levels of nutrients. The highest value of plant height at 40 DAS and at harvest (105.95 cm and 126.13 cm respectively), LAI at 20 DAS and at harvest (0.464 and 3.73 cm respectively) and leaf stem ratio at harvest (0.76) were recorded by the treatment receiving highest dose of vermicompost and chemical fertilizer (v_2f_2). Increasing levels of vermicompost and chemical fertilizer significantly increased the plant height at harvest, LAI at 40 DAS and at harvest and leaf stem ratio at harvest of cowpea. Application of vermicompost 5 t ha^{-1} and chemical fertilizer (100 per cent POP) recorded maximum values for plant height at harvest (105.7 cm), LAI at 40 DAS and at harvest (3.10 and 5.85 respectively) and leaf stem ratio at harvest (1.51).

At higher levels of vermicompost and chemical fertilizers the growth parameters were found to be responding well. This might be due to the increased availability of nutrients to plants. Worm casts were rich in available nutrients for plant growth (Tomati *et al.*, 1988) and had all qualities of a fertilizer (Bano *et al.*, 1987). As the level of organic manure was increased more of the nutrient nitrogen became available to the plants which might have increased the plant height. Influence of nitrogen in increasing the vegetative growth of the plant is a universally accepted fact. Increased plant height obtained at higher levels of vermicompost and chemical fertilizer is attributed to the rapid meristematic activity triggered by plant nutrients especially nitrogen (Crowther, 1935). A similar increase in plant height by vermicompost application was reported by Shuxin *et al.*, (1991) in sugarcane and soyabean. The present findings are also in agreement with the observations of Stolyarenko *et al.*, (1992) in maize and Shailajakumari and Ushakumari (2001) in cowpea.

Phosphorus is considered to be the king pin nutrient in pulse growing having a direct role in better root development and nitrogen fixation. Vermicompost application increased the availability of P to plants by higher phosphatase activity (Shuxin *et al.*, 1991) which increased the amount of nitrogen fixed and thereby development of shoot and other plant parts were influenced. This might have led to an increase in plant height of cowpea and *Sesbania rostrata*.

Among the four fodder crops, sorghum recorded the highest plant height followed by bajra at the time of harvest. Cowpea plants recorded the lowest plant height.

Leaf area index of all the fodder crops increased with increasing levels of vermicompost and chemical fertilizers. This increase might be due to higher nutrient content both from vermicompost and chemical fertilizers. As the nitrogen supply increased the extra protein produced might have allowed the plant leaves to grow larger and hence to have more surface area available for photosynthesis (Russel, 1973). Increase in LAI with incremental doses of nitrogen was shown by Barik *et al.* (1998) in sorghum. Vermicompost is reported to contain about three times more nutrients than farmyard manure (Prabhakumari *et al.*, 1995). Increased availability of P due to vermicompost application might have increased the supply of nitrogen for leaf expansion and thereby resulting in higher leaf area. Thus enhanced production of leaves and increased longevity of leaves exhibited by plants receiving high levels of nutrients might have increased the leaf area index of the crops. Steineek (1964) opined that more the available nitrogen the greater the effect of K on the growth of shoot, number of leaves and longevity of leaves.

Highest LAI at the time of harvest was recorded by cowpea plants followed by *Sesbania rostrata*. Bajra recorded the lowest LAI.

Leaf: stem ratio of both cereal and leguminous fodder crops increased with the application of higher levels of vermicompost and chemical fertilizers at each stage. The increased leaf:stem ratio may be due to the effect of significant quantities of available nutrients and biologically active metabolites present in vermicompost, which might have increased the production of leafy material compared to stem. Leaf stem ratio is an important character which indicates the leafiness of fodder. Increase in nitrogen supply due to vermicompost and fertilizer application might have increased the production, translocation and assimilation of photosynthates to growing points thereby stimulating plant to produce more number of leaves (Doikova *et al.*, 1984). Shivanand *et al.* (1987) also found significant increase in leaf: stem ratio with increasing levels of NPK in fodder sorghum.

Leaf: stem ratio decreased as the crop matured for all the four crops and was maximum at 20 DAS and least at harvest. Combined application of vermicompost and chemical fertilizers might have raised the availability of nutrients throughout the growing period which increased the photosynthetically active surface area and inturn higher photosynthates for providing more shoot growth. Increase in shoot length and shoot girth due to vermicompost application was reported by

Shuxin *et al.* (1991) in sugarcane and soyabean. This led to an increase in shoot weight with a lower value for leaf stem ratio in later stages. Increase in shoot weight due to application of vermicompost was reported by Stephens *et al.* (1994) in wheat.

At the time of harvest highest leaf stem ratio was recorded by cowpea. The stem and leaves of cowpea plants are more succulent compared to other crops. This resulted in higher leaf stem ratio of cowpea.

From the results it is clear that as the level of organic manure (vermicompost) and chemical fertilizers were increased, the vegetative growth was improved. Similar observations of enhanced growth characters by the dual application of chemical fertilizer with vermicompost was reported by Pushpa (1996).

5.2 Yield

5.2.1 Green fodder yield

Different levels of vermicompost significantly influenced the green fodder yield of all the four fodder crops. The highest green fodder yield was recorded with the application of vermicompost 5 t ha^{-1} in bajra (7533.26 kg ha^{-1}), sorghum (10791.12 kg ha^{-1}), *Sesbania rostrata* (17629.51 kg ha^{-1}) and cowpea (24358.88 kg ha^{-1}).

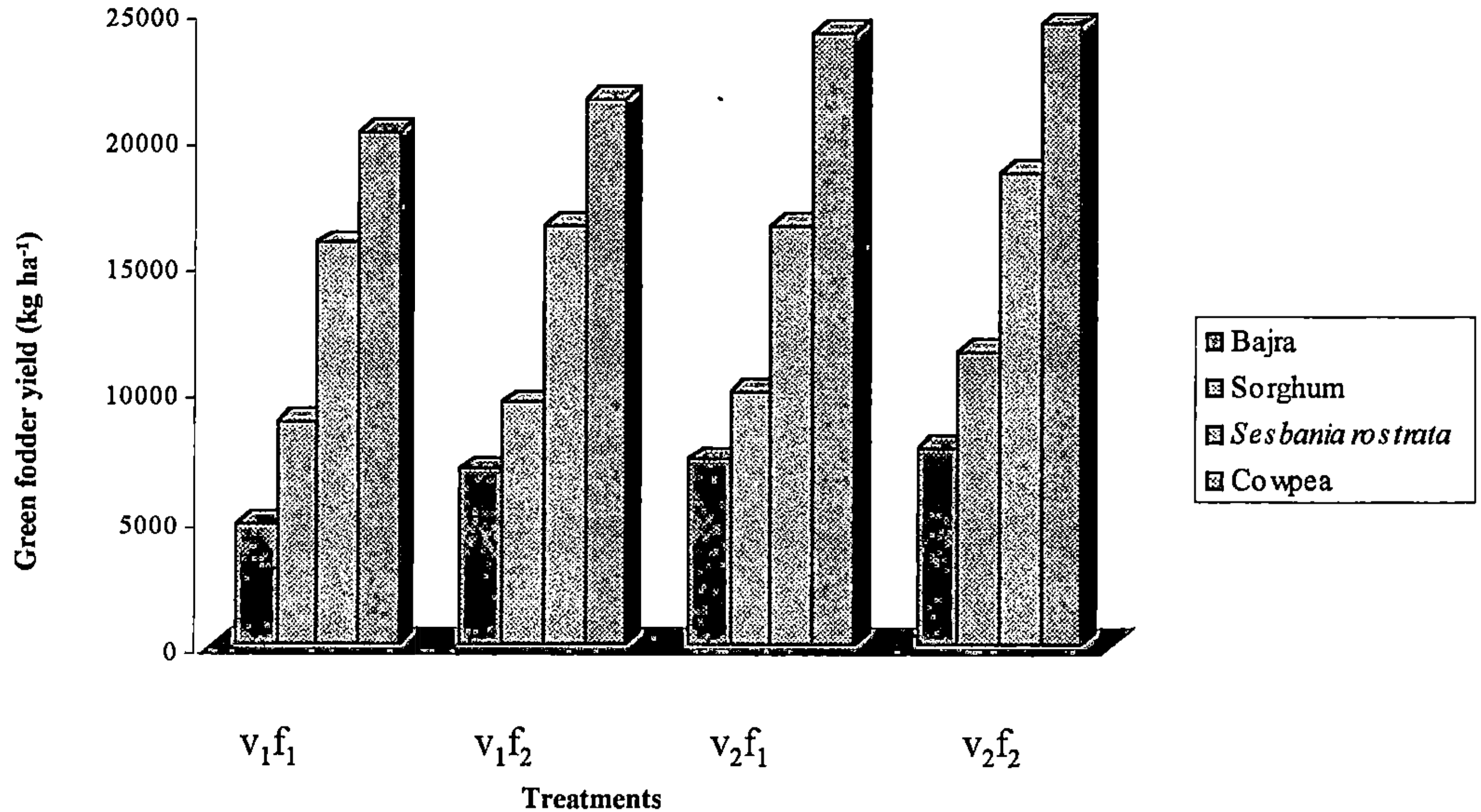


Fig. 3. Effect of different combinations of vermicompost and chemical fertilizers on green fodder yield (kg ha^{-1}) of fodder crops

Eventhough increase in fertilizer levels increased the green fodder yield of cereal and leguminous fodder crops a significant increase was noticed only in *Sesbania rostrata*.

The data of green fodder yield clearly indicate a progressive increase in green fodder yield with increasing levels of vermicompost and chemical fertilizers in both cereal and legume fodder crops though a significant response was shown only by *Sesbania rostrata* and cowpea. The treatment v_2f_2 recorded the maximum value for green fodder yield in bajra (7779.48 kg ha^{-1}), sorghum (11573.13 kg ha^{-1}), *Sesbania rostrata* (18339.64 kg ha^{-1}) and cowpea (24518.4 kg ha^{-1}).

Vermicompost can act not only as a growth determinant but also as an yield determinant. The increased green fodder yield may be due to the better nutrient content and soil improving property of vermicompost. Application of vermicompost have significantly contributed plant nutrients and growth promoting substances, which inturn have increased the uptake of nutrients and metabolic activity of plants (Nielson, 1965). Malik *et al*. (1992) observed enhanced leaf production in fodder sorghum with incremental levels of nitrogen. In legumes application of vermicompost stimulates microbial activity and enhances nitrogen fixation (Parkin and Berry, 1994). This increased amount of nitrogen fixed increased the growth characters of plants *viz*., plant height, leaf area index and leaf stem ratio which ultimately resulted in higher green fodder yield in cowpea and *Sesbania rostrata*.

The higher availability of plant nutrients created due to the improved physical environment brought about by vermicompost can be cited as the major reason for the above desirable effects. The increase in green fodder yield due to vermicompost application is a reflection of the growth attributes *viz.*, increased plant height, LAI and leaf stem ratio as a result of increased availability of nutrients. Enhancement in herbage production by increased nitrogen was reported by Shukla and Sharma (1994) in fodder sorghum and Gautum and Kaushik (1997) in pearl millet. Shuxin *et al.*, (1991) reported 50 per cent increase in weight of soyabean plants when vermicompost was applied.

Among the cereal fodders sorghum recorded the highest green fodder yield (11573.13 kg ha^{-1}) followed by bajra (7779.48 kg ha^{-1}) for the highest level of organic manure and inorganic source (v_2f_2). Cowpea produced the highest green fodder yield (24518.4 kg ha-1) among the leguminous fodder crops. The observation is in conformity with the findings of Rajasree (1994).

5.2.2 Dry fodder yield

The dry fodder yield was significantly influenced by vermicompost in bajra, *Sesbania rostrata* and cowpea. In sorghum

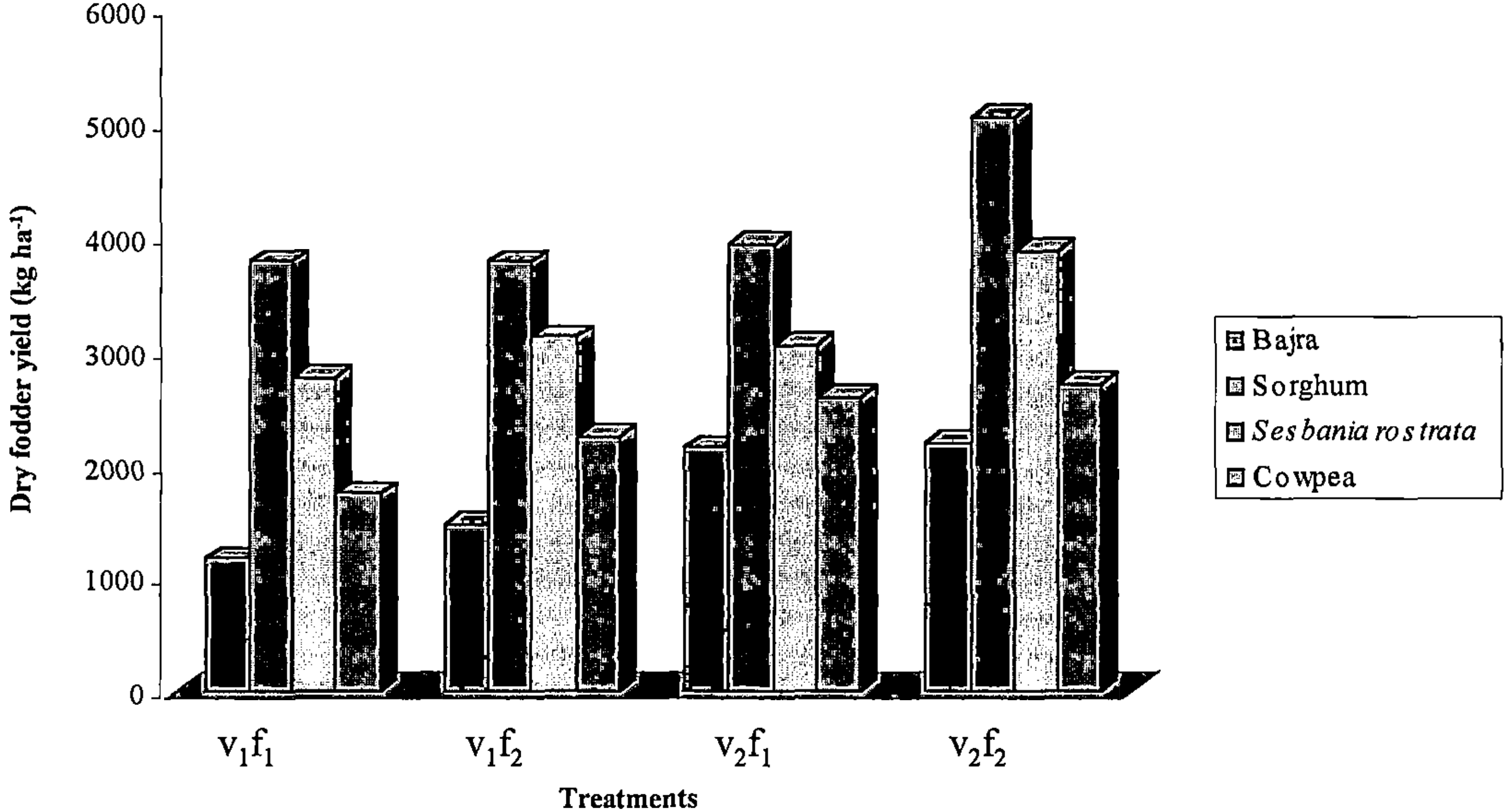


Fig. 4. Effect of different combinations of vermicompost and chemical fertilizers on dry fodder yield (kg ha^{-1}) of fodder crops

vermicompost application could not produce any significant increase in dry fodder yield. The highest level of vermicompost (5 t ha^{-1}) recorded the highest dry fodder yield in bajra (2144.26 kg ha^{-1}) *Sesbania rostrata* (3451.29 kg ha^{-1}) and cowpea (2634.53 kg ha^{-1}).

Different levels of fertilizer significantly increased the dry fodder yield of *Sesbania rostrata*. Though not significant, higher levels of fertilizer recorded more dry fodder yield in bajra, sorghum and cowpea.

Integrated application of different levels of vermicompost and chemical fertilizers could not produce any significant difference in the dry fodder yield of bajra and sorghum. A significant increase in dry fodder yield was noticed in the case of *Sesbania rostrata* and cowpea. The highest dose of fertilizer along with vermicompost 5 t ha^{-1} recorded the highest value for dry fodder yield in *Sesbania rostrata* (3867.56 kg ha^{-1}) and cowpea (2694.67 kg ha^{-1}).

The primary factor governing the soil health is the organic matter content of soil which is improved by the addition of more quantities of vermicompost. This might have resulted in better availability and uptake of nutrients which resulted in increased dry fodder yield. Increased nutrient uptake might have increased the photosynthetically active surface area and in turn higher photosynthates for providing more dry matter yield. Similar results were reported by Fierriere and Cruz (1992) in maize and Bijulal (1997) in cowpea. Singh and Singh (1999) obtained highest straw yield with the application of vermicompost 10 t ha^{-1} in wheat. Sudha (1999) also obtained highest straw yield in rice with the application of vermicompost @ 5 t ha^{-1}.

Among the four fodder crops sorghum recorded the maximum Dry fodder yield followed by *Sesbania rostrata*. Bajra recorded the lowest dry fodder yield.

5.3 Quality characters

5.3.1 Crude protein content

Protein content of fodder crops is of prime importance since it is considered as the building block of any living system. Increasing levels of vermicompost and fertilizers increased the crude protein content at all the stages of the four fodder crops. This may be due to the balanced availability of nitrogen throughout the growth stages. The increased nutrient uptake in vermicompost treated plots might have resulted in increased protein content. Similar results of increased nitrogen uptake by the application of vermicompost were reported by Shuxin *et al.*, (1991), Kale *et al.*,(1992) and Reddy and Mahesh (1995). As more and more nitrogen is available to plants, it is metabolized to glutamic acid. Glutamic acid is further converted to other amino acids which are stored as proteins (Tisdale *et al.*, 1995).

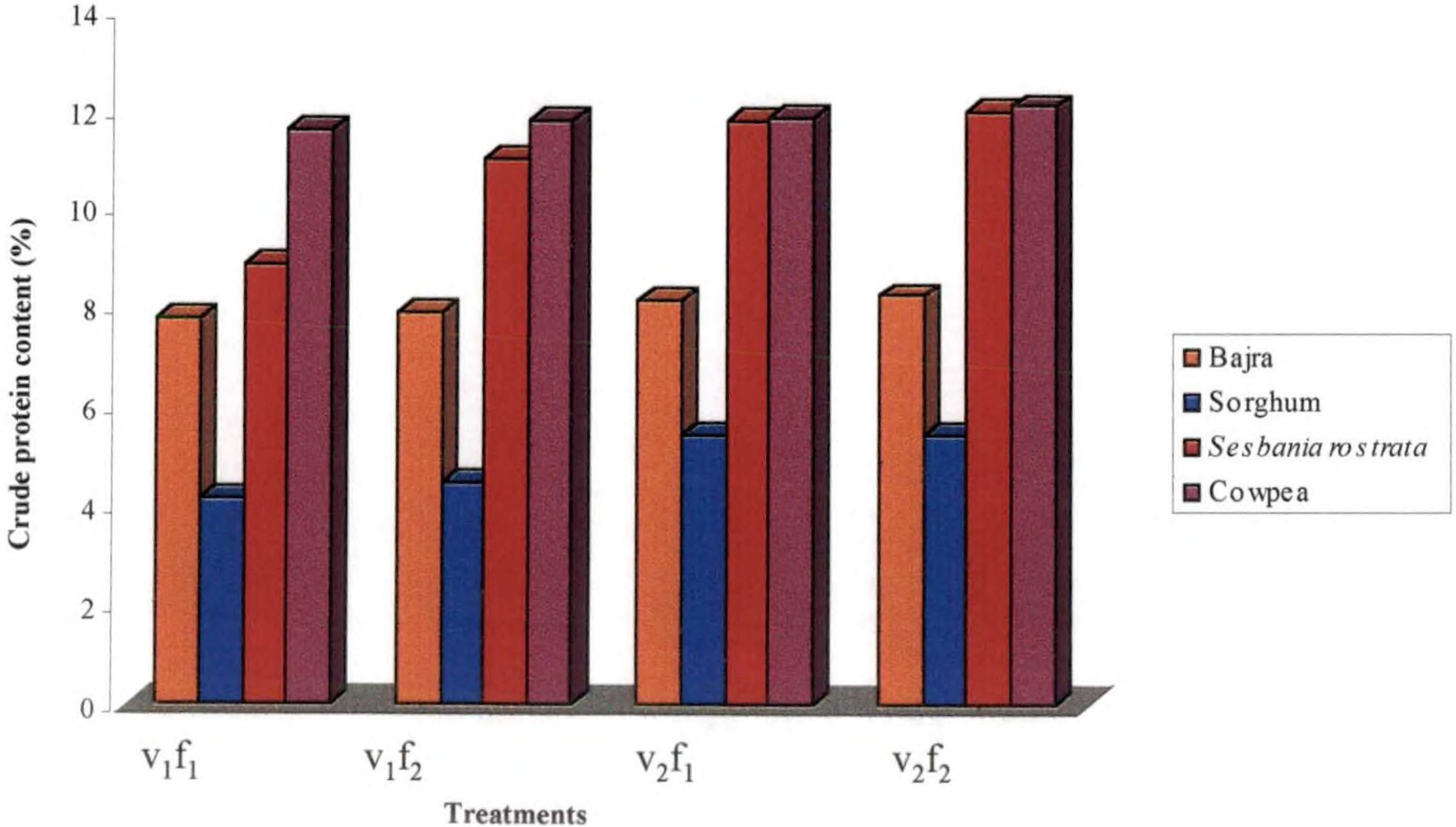


Fig. 5. Effect of different combinations of vermicompost and chemical fertilizers on crude protein content (%) of fodder crops at the time of harvest

In the case of cereal fodder crops application of higher levels of vermicompost increased the crude protein content of plants upto 20 DAS. There after it decreased and a slight increase was noticed at the time of harvest in bajra (50 per cent flowering). In sorghum a slight increase in crude protein content was noticed at 60 DAS and then it decreased until harvest. This findings corroborates with the findings of Korikanthimath and Palaniappan (1987) in sorghum. In legumes, crude protein content increased upto 40 DAS and then decreased. This decrease in crude protein content could be attributed to the translocation of nitrogen to reproductive organs.

Among the four fodder crops the highest crude protein content was recorded by cowpea which was closely followed by *Sesbania rostrata*. Sorghum recorded the lowest crude protein content

5.3.2 Crude fibre content

The crude fibre content determines the digestibility of the forage and it is an important criteria for evaluation of any forage material. Crude fibre content of all the four crops registered a significant decrease with increase in vermicompost and fertilizer levels and the lowest crude fibre content was recorded by the highest levels of vermicompost and chemical fertilizer (v_2f_2). The significant quantities of available nutrients, biologically active metabolites particularly giberellins,

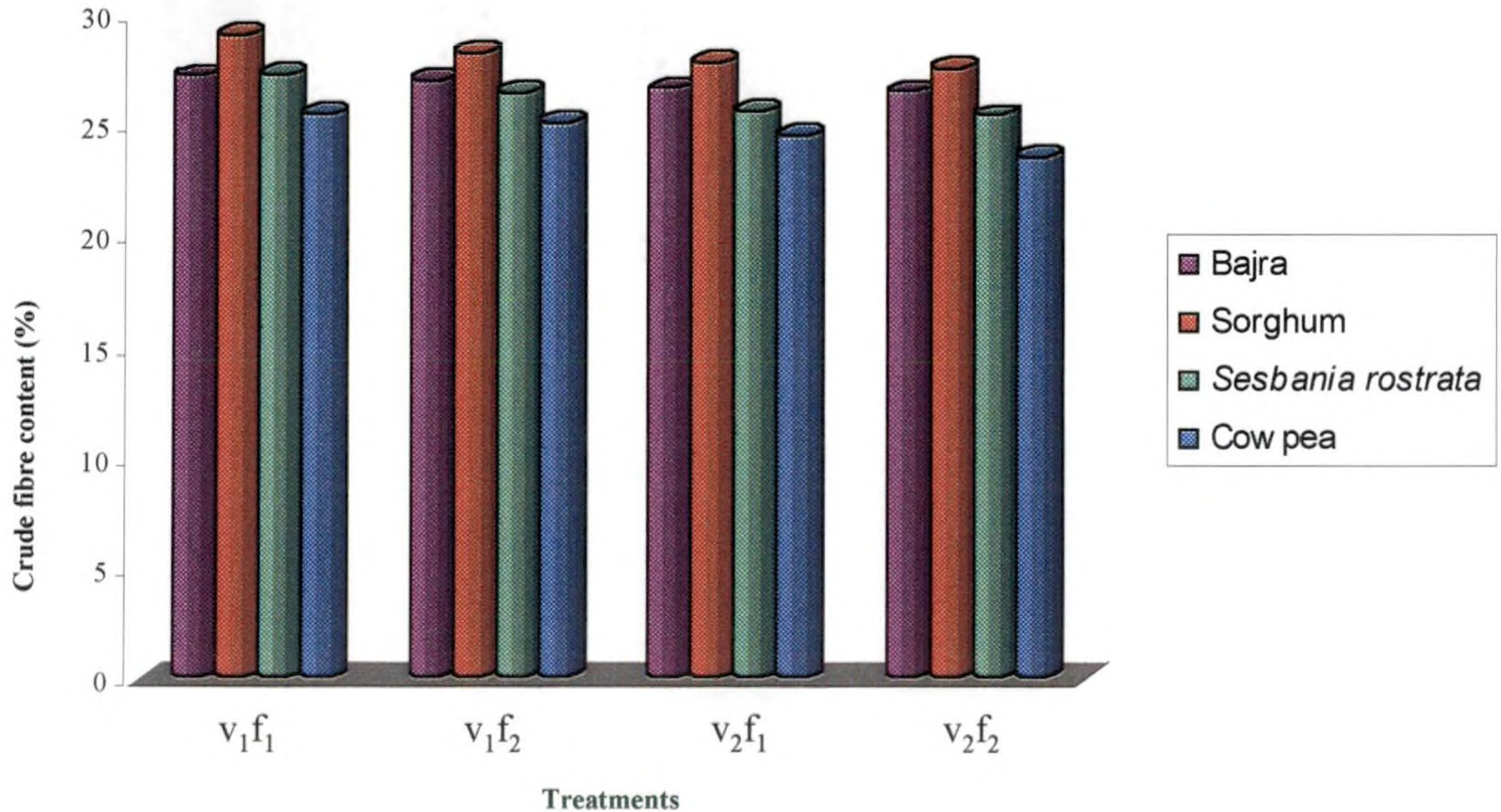


Fig. 6. Effect of different combinations of vermicompost and chemical fertilizers on crude fibre content (%) of fodder crops at the time of harvest

cytokinins, auxins and group B vitamins present in vermicompost might have contributed to decrease in crude fibre content. With higher content of nitrogen in the plants, the carbohydrates are utilized more for synthesis of protoplasm rather than for thickening of cell wall, resulting in more succulent and reduced fibre content as reported by Tiwana *et al.* (1975). The present results are in agreement with the findings of Arunkumar (2000). An inverse relationship between crude protein and crude fibre contents was reported by Balbatti (1980) in hybrid napier.

Increasing levels of fertilizers also significantly decreased the crude fibre content of fodder. Similar results of decreased crude fibre content with fertilizer application was noticed by Vineetha (1995) in gamba grass and Tiwana *et al.* (1975) in napier bajra hybrid.

V x F interaction was also found to be significant. The quality of fodder was improved when vermicompost was given along with inorganic fertilizers. This is in close agreement with Pushpa (1996) who reported the superiority of integrated application of chemical fertilizer and vermicompost.

Highest crude fibre content was recorded by sorghum followed by bajra. Cowpea recorded the lowest crude fibre content.

5.4 Nutrient content of the fodder

5.4.1 Nitrogen content of fodder

Nitrogen content of fodder crops increased with increasing levels of vermicompost and chemical fertilizer. The highest level of vermicompost and fertilizer (v_2f_2) recorded the highest nitrogen content in all the four fodder crops. The higher degree of decomposition and mineralisation in vermicompost may be one of the reasons for high nitrogen content. Kale *et al.* (1992) found significantly higher levels of uptake of N and P in rice treated with vermicompost. The nitrogen fixing organisms present in vermicompost might have increased the amount of nitrogen in soil which increased the uptake of nitrogen by the plants. The N and K levels of vermicompost are significantly higher and the N levels ranges from 1.4 to 2.14 per cent (Bano and Susheeladevi, 1996). Thirty to fifty per cent increase in nitrogen uptake in vermicompost applied plots was observed by Shuxin *et al.* (1991) in sugar cane. Application of vermicompost (5 t ha^{-1}) along with recommended dose of fertilizer increased the nutrient content of petioles of grapes (Venkatesh, 1995).

A gradual decrease in nitrogen content was observed with the advancement of growth stages. Highest nitrogen content was recorded at 20 DAS in the case of bajra and sorghum and at 40 DAS in the case of legumes. In sorghum a steady decline in nitrogen content was noticed after 60 DAS. Initial increase in the nutrient content may be attributed to their enhanced availability through faster mineralisation in an environment dominated by vermicompost (Stephens *et al.*, 1994). Decrease in nitrogen content towards the latter part of observation could be substantiated by the nutrient immobilization and translocation to the storage organs namely seeds through destructive senescence. Decline in nitrogen content towards the latter parts of growth was observed by Korikanthimath and Palaniappan (1987) in sorghum and Bijulal (1997) in cowpea.

Among the fodder crops highest nitrogen content was recorded by cowpea followed by Sesbania and bajra at the time of harvest. Sorghum recorded the least nitrogen content.

5.4.2 Phosphorus content of fodder

Phosphorus content of fodder was significantly influenced by the application of various levels of vermicompost and chemical fertilizer. An increasing trend was noticed with increase in nutrient levels. The increased mineralisation of native soil phosphorus as a result of production of organic acids during the decomposition of organic matter might be the reason for increased phosphorus content of plant parts. The solubilisation of P by the microorganisms was attributed to the excretion of organic acids like citric, glutamic, succinic, lactic, oxalic, glyoxalic, maleic, fumaric and tartaric acid (Rao, 1983). These reactions had taken place in the rhizosphere and since the organisms rendered more P into the solution than that required for their own growth and metabolism, the surplus was made available for the plant parts thereby increasing the P uptake and P content. This is in conformity with the findings of Syres and Springett (1984) and Shuxin *et al.* (1991) who had reported that the increased P availability was by an increase in solubility of P by higher phosphatase activity in presence of vermicompost application. P is an important structural component of a wide variety of biochemicals including nucleic acids, coenzymes, nucleotides, phophoprotein, phospholipids and sugar phosphates. Therefore it could be presumed that increased supply of nitrogen might result in increased production of P containing biochemicals under non limited conditions of P supply which would have contributed to improved P content in plants. Synergistic influence of nitrogen nutrition on P content was previously reported by Singh *et al.* (1970).

In bajra and sorghum highest P content was recorded at 20 DAS. In the case of *Sesbania rostrata* and cowpea phosphorus content showed an increase at the time of harvest.

5.4.3 Potassium content of fodder

Different levels of vermicompost and chemical fertilizers significantly influenced the K content of fodder. High K content in fodder might be due to the increased uptake of K. Vermicompost contain significant quantities of K (Bano and Susheeladevi, 1996). In the presence of vermicompost, the K fixation might have reduced there by releasing more K in the soil. The enhanced proliferation of roots might have helped in the increased uptake of K. Reddy and Mahesh (1995) reported an increase in the availability of K by the application of vermicompost. Increase in concentration of available and exchangeable K contents in casts compared to surrounding soil was reported by Lal and Vleeschauwar (1982) and Tiwari *et al.* (1989). Besides this, organic matter application in higher proportion would have resulted in vigorous root growth which might have increased the K content in plants.

Among the fodder crops cowpea plants recorded the highest K content at the time of harvest followed by *Sesbania rostrata*. Sorghum plants recorded the lowest K content.

5.5 Uptake of nutrients

5.5.1 Nitrogen uptake

Varying levels of vermicompost and fertilizers significantly influenced the nitrogen uptake of all the four fodder crops. Highest

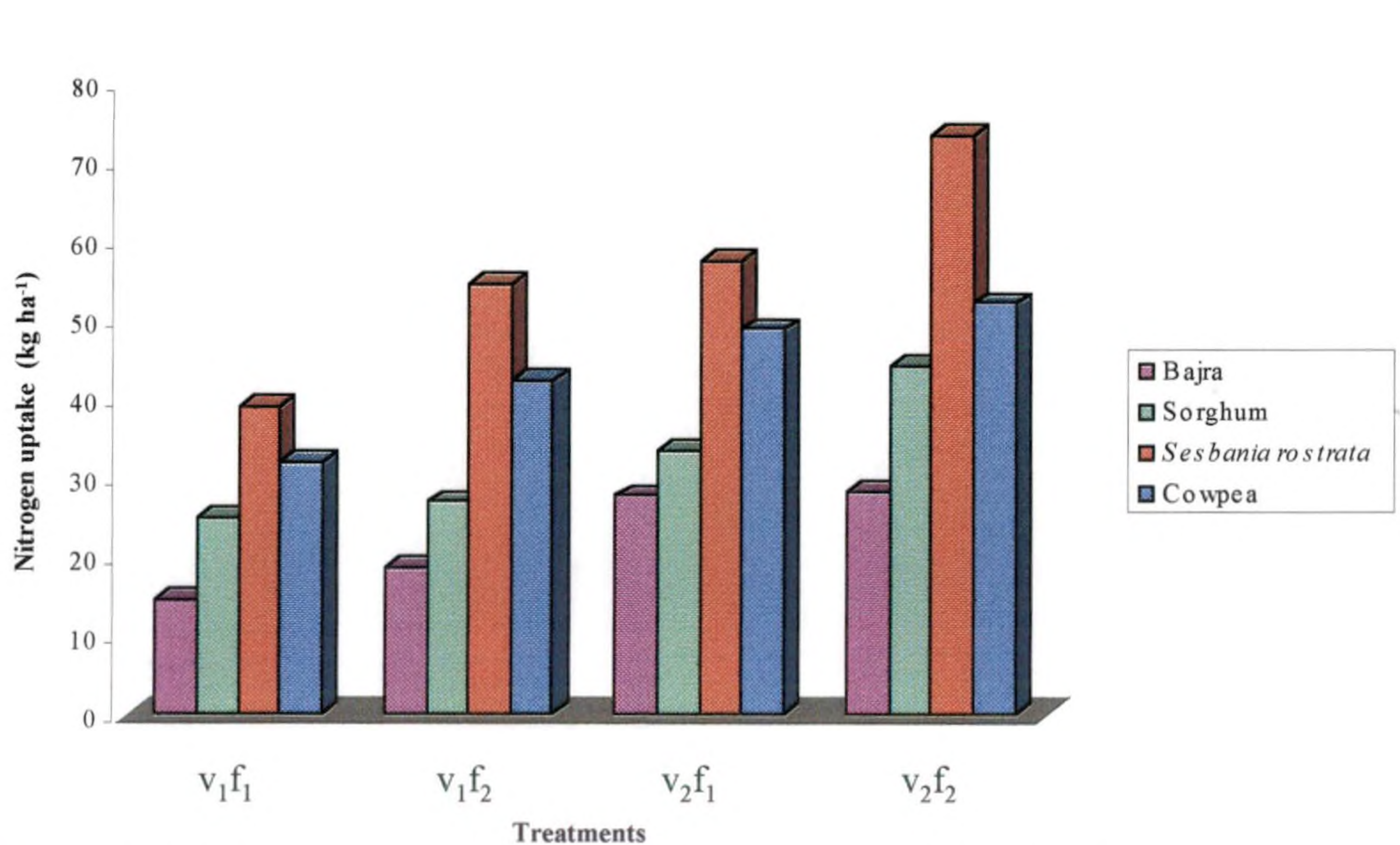


Fig. 7. Effect of different combinations of vermicompost and chemical fertilizers on nitrogen uptake (kg ha^{-1}) of fodder crops at the time of harvest

value for nitrogen uptake was obtained with the application of highest level of vermicompost and chemical fertilizer. Similar results were reported by Zao-shi-wei and Huong-Fu-Zhan (1988) in wheat and sugarcane who reported that chemical fertilizer application along with vermicompost increased the nutrient uptake by plants. Shuxin *et al.* (1991) also observed 30-50 per cent increase in nitrogen uptake in vermicompost applied sugarcane. Kale *et al.* (1992) found significantly higher levels of uptake of N and P in vermicompost treated plots in rice. Similar results of increased nitrogen uptake in cowpea was reported by Bijulal (1997).

The integrated application might have increased the microbial activity in soil which improve the N fixation. This view was supported by Parkin and Berry (1994). This enrichment of soil N due to N fixation might have led to increased uptake of nitrogen. Increase in uptake of nutrients with the integrated application of vermicompost and chemical fertilizer was reported by George and Pillai (1996) in Guinea grass.

Highest N uptake was recorded by *Sesbania rostrata* followed by cowpea. Bajra recorded the lowest N uptake.

5.5.2 Phosphorus uptake

Phosphorus uptake was significantly influenced by various levels of vermicompost and fertilizer. Highest P uptake was recorded with the

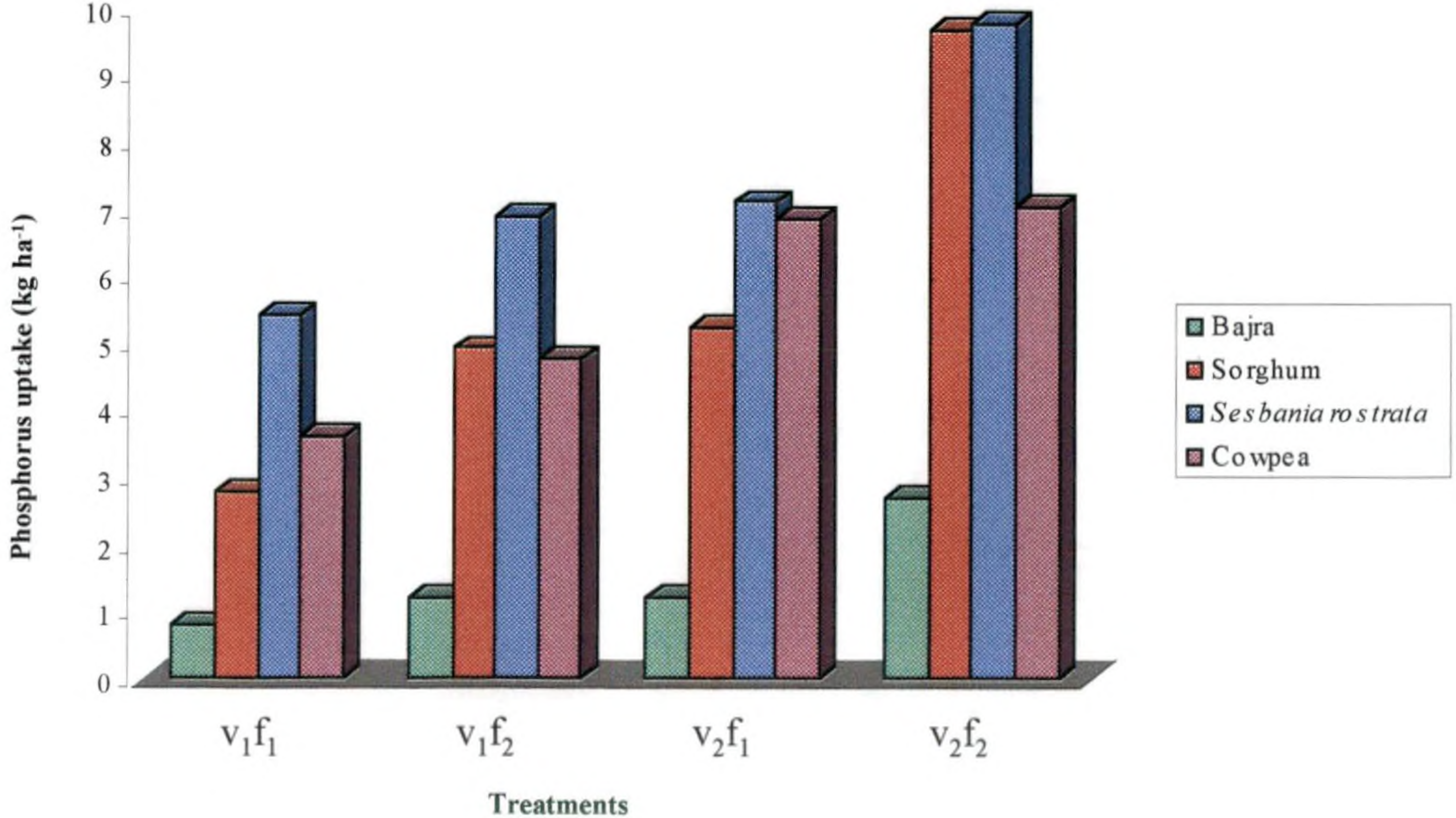


Fig. 8. Effect of different combinations of vermicompost and chemical fertilizers on phosphorus uptake (kg ha^{-1}) of fodder crops at the time of harvest

application of highest level of vermicompost and fertilizer (v_2f_2). Similar results were obtained by George and Pillai (1996) in guinea grass and Bijulal (1997) in cowpea. The increased mineralisation of native soil P as a result of production of organic acids during decomposition of organic matter might have increased the P uptake by plants. The earthworms stimulate P uptake by redistribution of organic matter and by increasing the enzymatic activation of phosphatase (Mackay *et al.*, 1982). Similar results were reported by Syres and Springett (1984). Indira *et al.* (1996) revealed the presence of beneficial microbes like P solubilising bacteria and N fixing organisms in vermicompost. The P solubilising microorganisms increase the available P content of vermicompost which might have increased the uptake of P by plants.

These may be the reasons for increased uptake of P in plots treated with higher levels of chemical fertilizers and vermicompost.

Highest P uptake was reported by *Sesbania rostrata* followed by sorghum.

5.5.3 Potassium uptake

Application of vermicompost (5 t ha^{-1}) and chemical fertilizer (100 per cent POP) significantly increased the K uptake of all the four fodder crops. Similar results of increased K uptake with the integrated

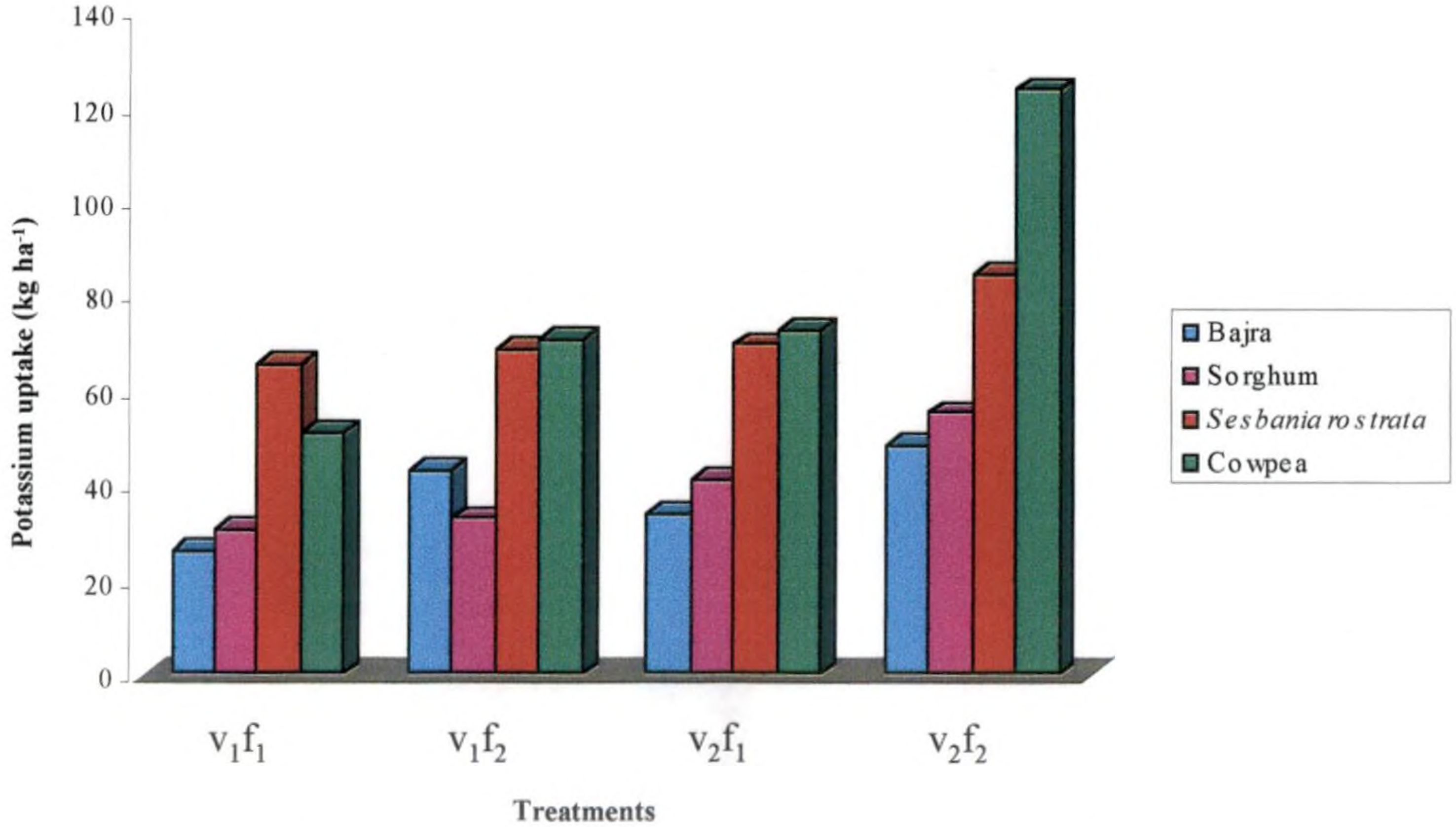


Fig. 9. Effect of different combinations of vermicompost and chemical fertilizers on potassium uptake (kg ha^{-1}) of fodder crops at the time of harvest

application of organic and inorganic sources of nutrient were reported by Brijlal and Dhyansingh (1998). Zachariah (1995) observed an increased K uptake in vermicompost treated plants. In the presence of vermicompost, the K fixation might have reduced thereby releasing more of K in the soil. Vasanthi and Kumaraswamy (1996) observed highest content of K in plots that received vermicompost along with NPK fertilizers in rice. The enhanced proliferation of roots might also have helped in increased uptake of K. As uptake of K is mostly through root interception, better the root system, the more is the K uptake. This agrees with the findings of Niranjana (1998).

Among the fodder crops highest K uptake was recorded by cowpea followed by *Sesbania rostrata*. Bajra recorded the lowest K uptake.

5.6 Soil physical properties

Significant differences in physical properties of the soil due to fodder cropping was noticed after the completion of experiment. Sesbania plots recorded the lowest bulk density and highest water holding capacity.

Different levels of vermicompost and fertilizers significantly influenced the physical properties of the soil. Highest level of vermicompost and chemical fertilizer recorded the lowest bulk density and highest water holding capacity. Vermicompost enhances the soil

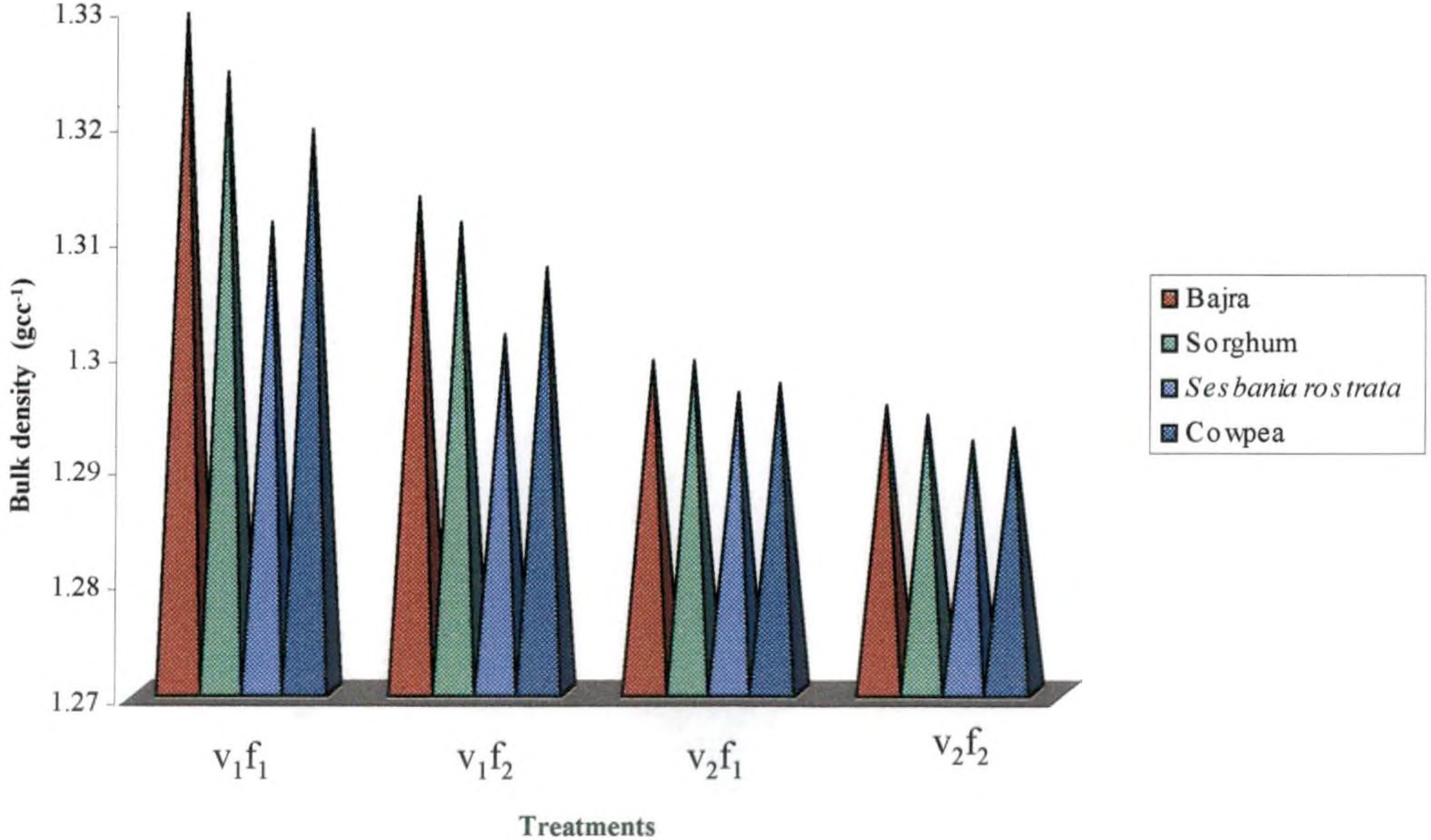


Fig. 10. Effect of different combinations of vermicompost and chemical fertilizers on bulk density of soil (gcc^{-1})

structure and improves the water holding capacity and porosity of soil to facilitate the root respiration and growth (Lee, 1985). George (1996) reported that vermicompost application lowered the bulk density and increased the water holding capacity of soil.

Fodder crops x nutrient levels interaction significantly influenced the physical properties of soil. Application of vermicompost 5 t ha^{-1} and chemical fertilizer (100 per cent POP) in sesbania plot recorded the lowest bulk density and highest water holding capacity.

5.7 Nutrient status of soil

5.7.1 Organic carbon content of soil

Different fodder crops could not produce any significant change in organic carbon status of soil after the experiment.

Organic carbon status of soil was favourably influenced by different levels of vermicompost and chemical fertilizers. Increasing levels of organic and inorganic sources of nutrients increased the organic carbon status. Similar observations have been made by Kamalakumari and Singaram (1996) and Sharma and Gupta (1998). The increase in organic carbon content is attributed to the high amount of organic carbon contributed by the compost material added. The carbon content in vermicompost ranged from 23.6 to 30 per cent (Bano and

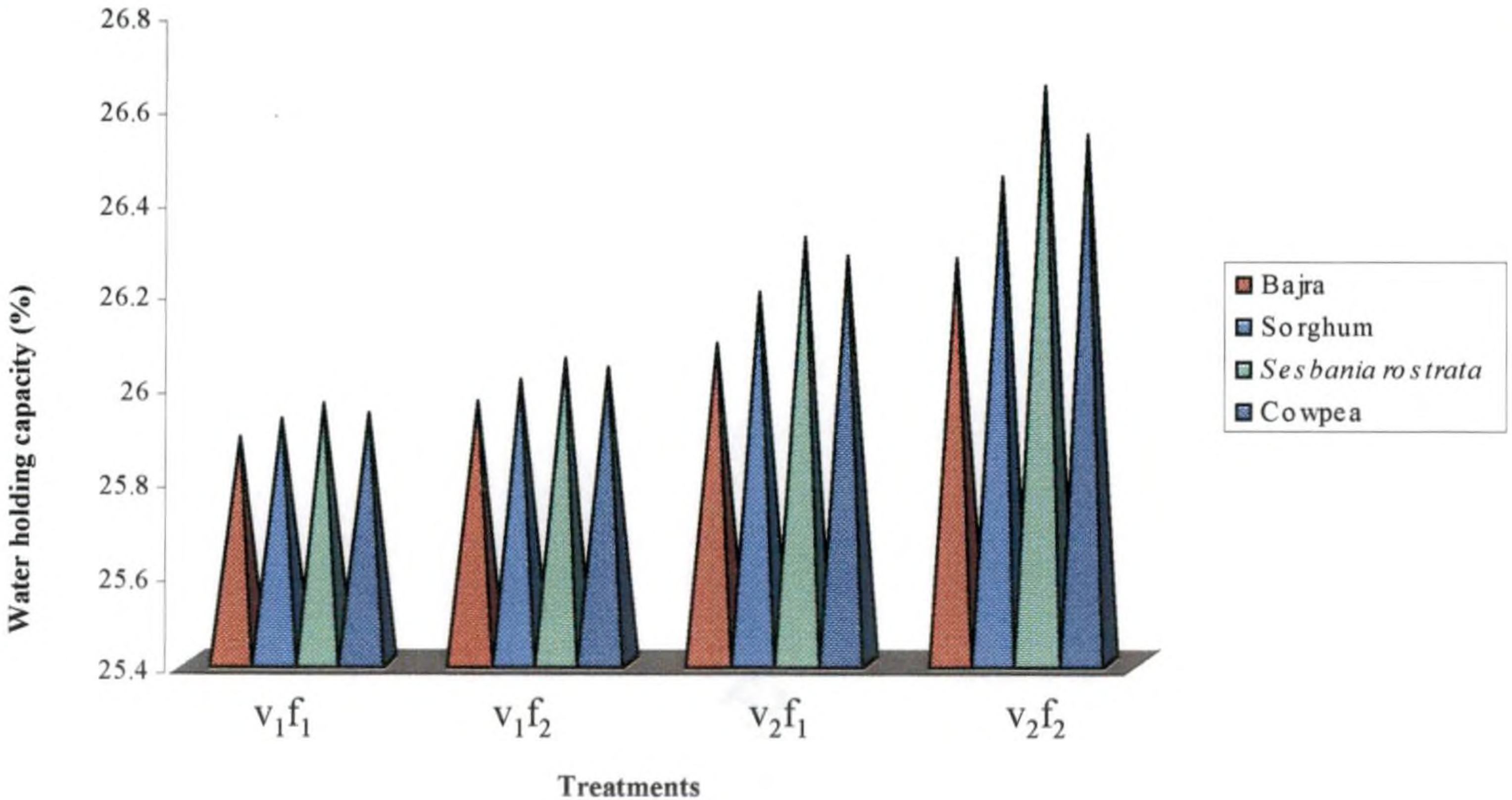


Fig. 11. Effect of different combinations of vermicompost and chemical fertilizers on water holding capacity (%) of soil

Susheeladevi, 1996). Sarawad *et al.* (1996) reported that application of vermicompost increased the organic carbon content of sorghum plots.

5.7.2 Available nitrogen content

Available nitrogen status in soil after the experiment was significantly influenced by different fodder crops. *Sesbania rostrata* recorded the maximum available nitrogen in soil where as other crops were on par with each other. This might be due to the higher N fixing capacity of *Sesbania rostrata*. It produces profuse nodules on both root and stem. The amount of N contributed by *Sesbania rostrata* was estimated to be around 200 kg N ha^{-1} during its active growth stage (Rinaudo *et al.*, 1982).

Increasing levels of vermicompost and chemical fertilizer increased the available N content of soil after the conduct of the experiment. The results were in confirmity with the findings of Kale *et al.* (1992) in paddy who had reported a high level of total N in the experimental plot receiving half the recommended dose of chemical fertilizer and vermicompost Vasanthi and Kumaraswamy (1996) also noticed an increase in available N status with the application of vermicompost + NPK in rice. The increase in available N content of soil and increased N recovery due to the use of organic source of nitrogen has been reported by Srivastava (1985). It is reported that

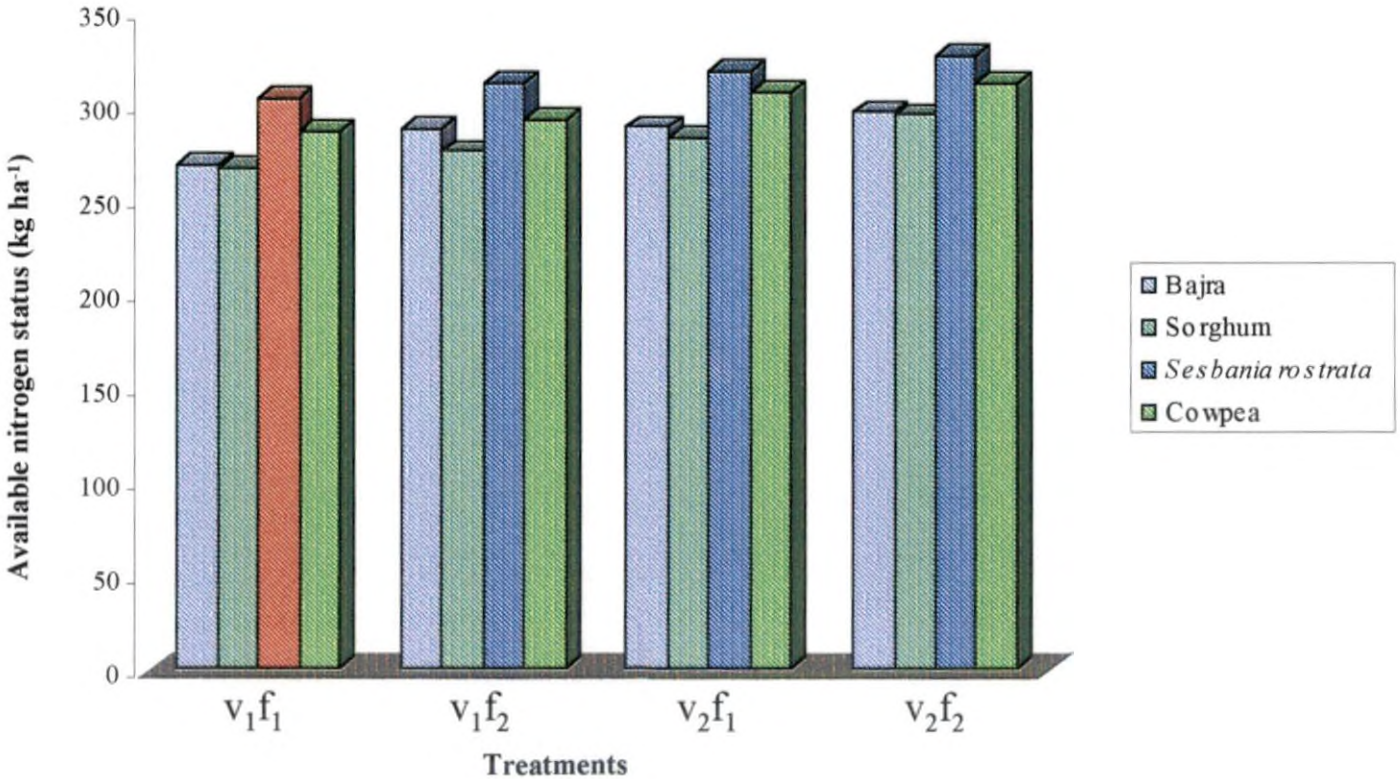


Fig. 12. Effect of different combinations of vermicompost and chemical fertilizers on available nitrogen status (kg ha^{-1}) of soil

vermicompost has a high urease activity than soil and other compost materials (Bremner and Mulvaney, 1978). The higher degree of decomposition and mineralisation in vermicompost may be one of the reasons for high N content in worm casts and this might have finally contributed to the available N status of soil. N fixing organisms present in vermicompost may fix atmospheric N in significant quantities which also increase available nitrogen in the soil (Lee, 1992).

5.7.3 Available phosphorus content

Different fodder crops significantly influenced the available phosphorus in soil after the experiment and it was maximum under cowpea. Similar results of high available soil P content under cowpea variety C-152 was reported by Rajasree (1994). The low P uptake would have resulted in high available P in soil after the conduct of the experiment. Sesbania plots recorded the lowest available P. This might be due to the higher uptake of P by the plants.

Available P in soil was significantly influenced by the application of varying levels of vermicompost and chemical fertilizers. The highest level of vermicompost and chemical fertilizer recorded the highest available P in soil. The combined application of chemical fertilizer and organic manure is important to maintain and sustain a higher level of soil fertility and crop productivity. The results are in confirmity with

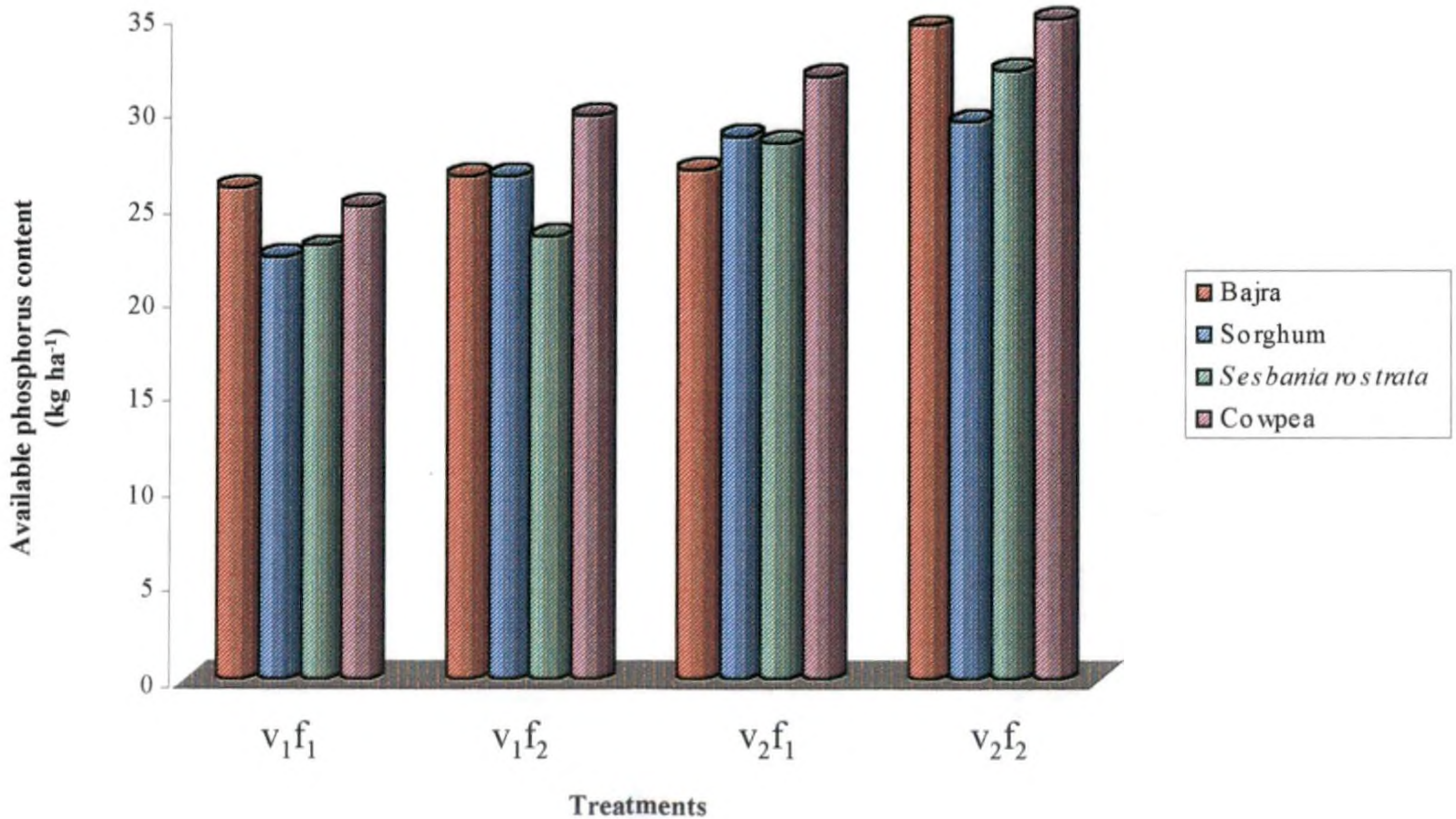


Fig. 13. Effect of different combinations of vermicompost and chemical fertilizers on available phosphorus content (kg ha^{-1}) of soil

the findings of Sharma and Gupta (1998) and Vasanthi and Kumaraswamy (1996). Increase in available P_2O_5 content of soil with the application of vermicompost was reported by George (1996) and Gaur (1990). The higher P content of vermicompost might have reflected in higher P status of the soil. The increased mineralisation of native soil P as a result of production of organic acids during decomposition of organic matter might be one of the reasons for increased P status of soil. Indira *et al.* (1996) revealed the presence of beneficial microorganisms like P solubilising bacteria in vermicompost. The solubilisation of P by microorganisms was attributed to the excretion of organic acids like citric, glutamic, succinic, lactic, oxalic, glyoxalic, maleic, fumaric and tartartic acid (Rao, 1988). Higher phosphatase activity in the presence of vermicompost also increases the solubility of P. These may be the reasons for increased availability of P in plots treated with higher levels of vermicompost and chemical fertilizers.

Significant interaction was noticed with fodder crops x nutrient levels. Application of highest level of vermicompost (5 t ha^{-1}) and chemical fertilizer (100 per cent POP) recorded the highest available P status of soil in all the crops and v_2f_2 was significantly superior to all other treatment except in sorghum where v_2f_2 was on par with v_2f_1.

Highest available P status in soil might be due to the highest content of P in vermicompost and chemical fertilizer.

5.7.4 Available potassium content

Available potassium content of soil was significantly influenced by different fodder crops. Available potassium content in soil was highest under bajra. This can be attributed to the lowest K uptake by the plants. Highest K uptake was recorded by cowpea plants and the plots were cowpea was cultivated recorded the lowest available K status in soil.

Increasing levels of vermicompost and chemical fertilizer significantly increased the available potassium status in soil. The highest level of nutrient (v_2f_2) recorded the maximum K content in soil. The results are in confirmity with the findings of Sudha (1999) and Vasanthi and Kumaraswamy (1996) in rice who reported highest potassium status in soil with the application of vermicompost along with NPK. Increased available potassium content in soil in vermicompost treated plots may be due to the increased K content in vermicompost. The increased available status of K in soil due the addition of vermicompost may be due to the increased concentration of available and exchangeable K contents in worm casts compared to surrounding soil. Earth worms increases the availability of K by shifting the

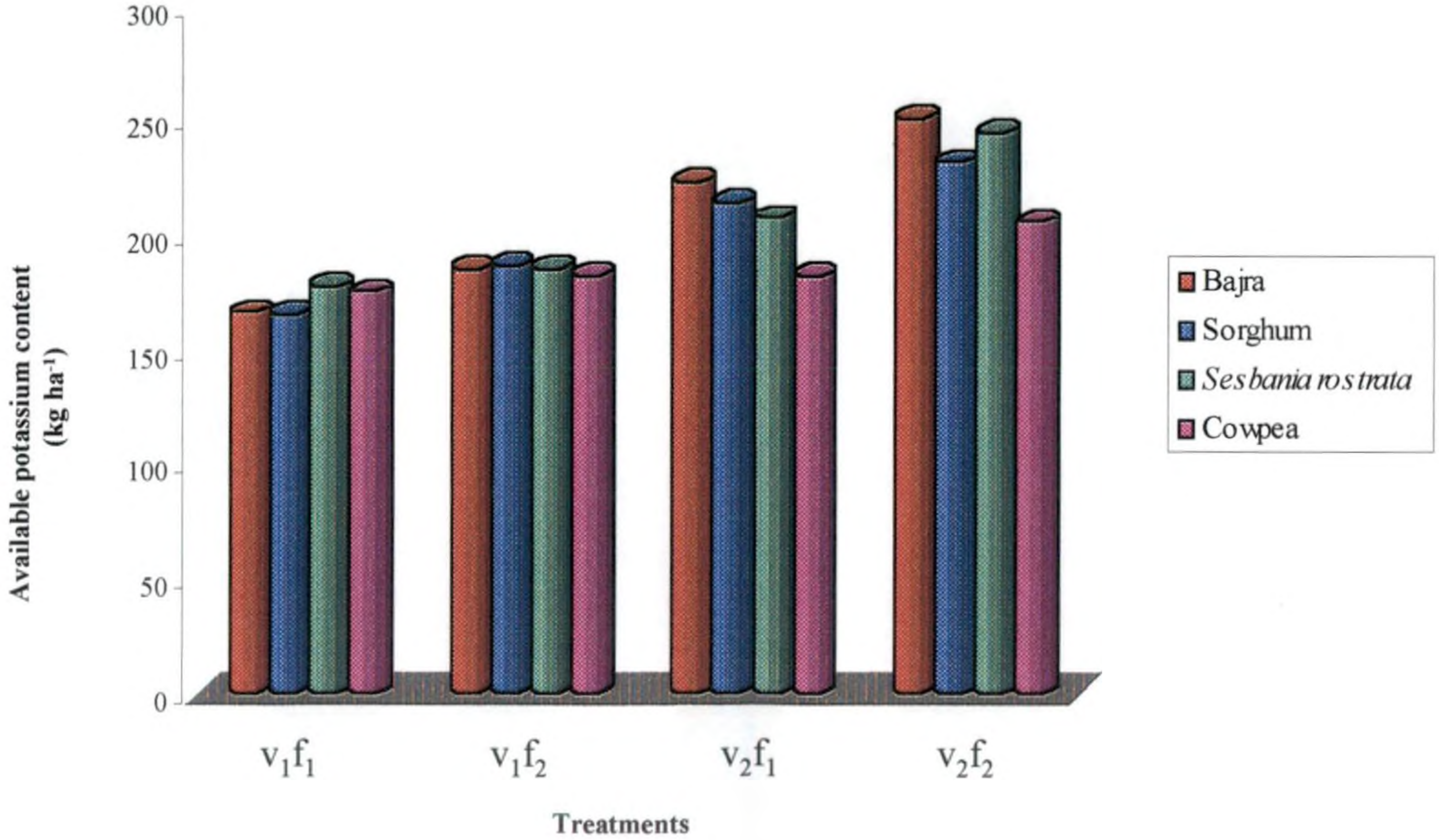


Fig. 14. Effect of different combinations of vermicompost and chemical fertilizers on available potassium content(kg ha^{-1}) of soil

equilibrium among the forms of K from relatively unavailable forms to more available forms (Basker *et al.*, 1992).

Fodder crops x nutrient levels interaction significantly influenced the available potassium content after the experiment. In all the crops the higher levels of vermicompost and chemical fertilizer application increased the available soil potassium content. The highest available potassium status of soil was recorded by the highest levels of vermicompost and chemical fertilizers in bajra.

UMMARY

SUMMARY

The study entitled "Evaluation and nutritional management of fodder crops in summer rice fallows" was carried out at the Cropping System Research Centre, Karamana, Thiruvananthapuram during February, 2000 to May, 2000. The objectives of the study were to evaluate the production potential and quality of different fodder crops in summer rice fallows under different nutrient levels, to study the changes in physico-chemical properties of soil due to fodder cropping and to work out the economics of fodder production.

The experiment was laid out in split plot design with four replications. The treatments consisted of two levels of vermicompost (2.5 t ha^{-1} and 5 t ha^{-1}) and two levels of chemical fertilizers (50 per cent POP recommendation and 100 per cent POP recommendation) as sub plot factor and two cereal fodder crops (sorghum and bajra) and two leguminous fodder crops (*Sesbania rostrata* and cowpea) as main plot factors, thereby forming sixteen treatment combinations.

The salient findings of the experiment are summarised below:

1. Plant height of all the four fodder crops were significantly increased by the integrated application of vermicompost and chemical fertilizers. Maximum plant height was recorded with

the application of vermicompost 5 t ha^{-1} and 100 per cent POP recommendation in all the crops.

2. Among the four fodder crops sorghum produced the tallest plants followed by *Sesbania rostrata*. Cowpea produced the shortest plants.
3. Leaf area index of all the four fodder crops increased progressively with incremental doses of vermicompost and chemical fertilizers. The highest level of vermicompost and chemical fertilizers recorded the maximum leaf area index.
4. Cowpea recorded the highest LAI among the four fodder crops, followed by *Sesbania rostrata*. Bajra recorded the lowest LAI. Leaf Area Index of the crops showed a progressive increase from 20 DAS to harvest.
5. Different combinations of vermicompost and chemical fertilizers significantly influenced the leaf stem ratio of all the fodder crops at the time of harvest. The highest level of vermicompost (5 t ha^{-1}) in combination with the highest level of chemical fertilizer (100 per cent PO) produced the highest leaf : stem ratio.
6. Leaf : stem ratio of all the four crops showed a decreasing trend towards harvest. Maximum value for leaf: stem ratio was obtained at 20 DAS and the least value at harvest.

7. Among the four fodder crops the highest leaf: stem ratio at harvest was recorded by cowpea followed by sorghum. *Sesbania rostrata* recorded the lowest leaf: stem ratio.
8. The green fodder yields of all the fodder crops were profoundly increased by the application of vermicompost. The highest dose of vermicompost produced the maximum green fodder yield. The highest level of vermicompost (5 t ha^{-1}) in combination with the highest level of chemical fertilizers (100 per cent POP) produced the maximum green fodder yield.
9. Among the four fodder crops, the highest green fodder yield was recorded by cowpea followed by *Sesbania rostrata*. Bajra recorded the lowest green fodder yield.
10. Maximum dry fodder yield was obtained with the application of vermicompost (5 t ha^{-1}) and 100 per cent POP recommendation in all the four fodder crops.
11. Sorghum recorded the highest dry fodder yield among the four fodder crops and was followed by *Sesbania rostrata*. Bajra recorded the lowest dry fodder yield.
12. Increasing the levels of vermicompost and fertilizers increased the crude protein content of fodder crops at all the stages and among the four fodder crops, the highest crude protein content

was recorded by cowpea which was closely followed by *Sesbania rostrata*. Sorghum recorded the lowest crude protein content.

13. Incremental levels of vermicompost and chemical fertilizers reduced the crude fibre content of fodder crops to a significant extent. The highest level of vermicompost combined with the highest level of chemical fertilizers produced the lowest crude fibre content.
14. An inverse relationship was observed between nutrient levels and crude fibre content of fodder crops.
15. The lowest crude fibre content was recorded by cowpea followed by *Sesbania rostrat*a. Sorghum recorded the highest crude fibre content.
16. Nitrogen content of fodder crops increased with increasing levels of vermicompost and chemical fertilizers. The highest level of vermicompost (5 t ha^{-1}) combined with highest level of chemical fertilizers (100 per cent POP recommendation) recorded the highest nitrogen content in all the four fodder crops.
17. Among the four fodder crops, highest nitrogen content was recorded by cowpea followed by *Sesbania rostrata*. Sorghum recorded the lowest nitrogen content.
18. An increasing trend in phosphorus content of fodder was noticed with increase in nutrient levels.

19. Potassium content of all the fodder crops showed a marked increase with increase in levels of vermicompost and chemical fertilizers.
20. Highest potassium content at the time of harvest was recorded by cowpea followed by *Sesbania rostrata*. Sorghum recorded the lowest potassium content.
21. The uptake of N, P and K was significantly increased when highest doses of vermicompost was combined with highest dose of chemical fertilizers.
22. Highest nitrogen uptake was recorded by *Sesbania rostrata* followed by cowpea. Bajra recorded the lowest nitrogen uptake.
23. *Sesbania rostrata* recorded the highest phosphorus uptake among the four fodder crops followed by sorghum.
24. Cowpea recorded the highest potassium uptake followed by *Sesbania rostrata*. Bajra recorded the lowest uptake of potassium.
25. Soil physical properties were improved by the application of vermicompost and chemical fertilizers. Application of vermicompost 5 t ha^{-1} and 100 per cent POP recommendation recorded the lowest bulk density and highest waterholding capacity.

26. Leguminous fodder crops reduced the bulk density of soil than cereal fodder crops. Lowest bulk density was recorded with *Sesbania rostrata* followed by cowpea.

27. Waterholding capacity of soil increased with the cultivation of leguminous fodder crops than with the cultivation of cereal fodder crops. *Sesbania rostrata* plot recorded the highest water holding capacity and bajra plots recorded the lowest water holding capacity.

28. Organic carbon content of soil was favourably influenced by combination of different levels of vermicompost and chemical fertilizers.

29. The available nitrogen status of the soil was significantly influenced by the cultivation of different fodder crops. *Sesbania rostrata* produced the highest available nitrogen content in soil.

30. The combined application of vermicompost 5 t ha^{-1} and 100 per cent POP.recorded the maximum available nitrogen status of soil.

31. Available soil phosphorus status was highest in plots grown with cowpea and lowest in plots with *Sesbania rostrata.*

32. The highest dose of vermicompost combined with highest dose of chemical fertilizers recorded the maximum phosphorus content of soil.

33. Available soil potassium status was highest with the cultivation of bajra and lowest with the cultivation of cowpea.

34. The highest level of nutrients recorded the maximum available potassium content of soil.

35. Highest B:C ratio was obtained with the cultivation of fodder cowpea.

36. Fodder legumes became ready for harvest 51 days after sowing. While sorghum took 50 more days to harvest. From this it is clear that we can raise two crops of cowpea or *Sesbania rostrata* if we grow fodder legumes instead of sorghum, which would be beneficial.

Future line of work

Summer rice fallows offer a good opportunity for fodder cultivation in our state. New types of good quality leguminous fodder crops may be tried to increase the productivity per unit area. Considering the beneficial effects of integrated application of vermicompost and chemical fertilizers on plant and soil, it would be more appropriate to undertake studies on the various combinations of other organic manures like poultry manure, neem cake, enriched compost etc.

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* Originals not seen

APPENDIX

APPENDIX – I

Weather data for the crop period-weekly averages

(February 2000 – May 2000)

Sl. No.	Standard week	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative humidity (%)	Rainfall (nm)
1.	7	32.6	23.2	85.6	0.6
2.	8	32.9	23.3	84.0	1.14
3.	9	33.4	23.7	84.1	0.14
4.	10	33.6	24.3	83.0	0
5.	11	34.1	24.3	79.7	0
6.	12	34.1	23.9	81.3	2.4
7.	13	33.7	24.6	83.1	7.6
8.	14	32.1	23.4	83.1	11.1
9.	15	33.0	25.4	80.0	0
10.	16	33.4	25.0	81.8	5.4
11.	17	32.9	25.6	82.4	0
12.	18	33.8	25.6	78.1	0
13.	19	34.1	25.6	76.4	0
14.	20	34.0	25.0	76.1	0.14
15.	21	35.0	25.0	74.0	0.14

EVALUATION AND NUTRITIONAL MANAGEMENT OF FODDER CROPS IN SUMMER RICE FALLOWS

By

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ABSTRACT OF THE THESIS
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ABSTRACT

A field experiment was conducted at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram during February, 2000 – May, 2000 to evaluate the production potential and quality of different fodder crops in summer rice fallows and to study the changes in physio-chemical properties of soil due to fodder cropping and to workout the economics of fodder production. The treatment consisted of combined application of two levels of vermicompost (2.5 t ha^{-1} and 5 t ha^{-1}) and two levels of chemical fertilizers (50 per cent and 100 per cent POP recommendation) on two cereal fodders (bajra and sorghum) and two leguminous fodders (*Sesbania rostrata* and cowpea). The experiment was laid out in split plot design with four replications.

Plant height, leaf area index and leaf: stem ratio differed significantly with the application of different combinations of vermicompost and chemical fertilizers. All these parameters were found to be increasing with increasing levels of vermicompost and chemical fertilizers. Integrated application of vermicompost (5 t ha^{-1}) and chemical fertilizers (100 per cent POP recommendation) produced the maximum value for all the growth parameters.

The green fodder yield and dry fodder yield of all the fodder crops were favourably enhanced by vermicompost application. Application of

highest dose of vermicompost combined with the highest dose of chemical fertilizers recorded the maximum fodder yield in all the four fodder crops.

Crude protein content of fodder crops increased with incremental doses of nutrients where as crude fibre content decreased with incremental doses of vermicompost and chemical fertilizers.

Incremental doses of the vermicompost and chemical fertilizers decreased the bulk density of soil where as water holding capacity increased with higher doses of nutrients.

Available nitrogen, phosphorus and potassium status of soil were improved and showed an increasing trend with the increasing levels of vermicompost and chemical fertilizers.

Green fodder yield was maximum in cowpea while dry fodder yield was maximum in sorghum.

Cowpea plants recorded the highest crude protein content, nitrogen content and potassium content followed by *Sesbania rostrata*. Sorghum recorded the highest crude fibre content and cowpea recorded the lowest crude fibre content.

The uptake of nitrogen and phosphorus were maximum in *Sesbania rostrata* whereas cowpea recorded the maximum potassium uptake.

Leguminous fodder crops improved the physical properties of soil *viz*. bulk density and water holding capacity. *Sesbania rostrata* produced the highest available nitrogen status of soil.

The present investigation revealed that an integrated application of vermicompost and chemical fertilizers was beneficial for increasing the growth, yield and quality characters of fodder crops. The physical and chemical properties of soil was also improved. Among the fodder crops, cowpea was found to be more economical as a fodder crop in summer rice fallow condition.