NITROGEN FIXATION BY COWPEA AS INFLUENCED BY THE STAGE OF GROWTH AND DURATION OF CROP

By

INDIRA. M.

THESIS
submitted in partial fulfilment of the
requirement for the degree
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Soil Science and Agriculture Chemistry
COLLEGE OF AGRICULTURE
Vellayani, Trivandrum

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DECLARATION

I hereby declare that this thesis entitled "Nitrogen fixation by cowpea as influenced by the stage of growth and duration of crop" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or society.

Vellayani,
2nd May, 1985.

(INDIRA, M.)

CERTIFICATE

Certified that this thesis entitled "Nitrogen fixation by cowpea as influenced by the stage of growth and duration of crop" is a record of research work done independently by Kum. INDIRA, M. 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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Chairman,
Advisory Committee
Associate Professor of Soil Science and Agricultural Chemistry

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INDIRA, M.

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INTRODUCTION

INTRODUCTION

The legume - Rhizobium symbiosis is considered the most promising plant bacteria association for immediate nitrogen enrichment of soil through biological nitrogen fixation in the tropics. Harnessing such biological fixation of nitrogen for agriculture in tropics is gaining importance in recent years in view of chemically fixed nitrogen becoming more and more scarce and costly.

Addition to the total pool of soil nitrogen through fixation by legumes may vary depending upon the efficiency of the components of the symbiotic system. It is related to the genetic potential for nitrogen fixation of the symbiont as well as the Rhizobium sp., the prevailing environmental factors and soil nutrient status. It is also determined by the type of utilisation of the legume, i.e. whether they are being used as a green manure or fodder, vegetable or grain.

Common legumes like cowpea, greengram and calapagonium have been reported to accumulate nitrogen in excess of 300 kg per hectare in 12 to 14 weeks (Agboola and Fayemi, 1972). Accretion of soil nitrogen under a mixed legume-gram cropping system may come to an average of 200 kg/ha/year (Moore, 1962). Much lower amounts of nitrogen is known to be fixed by several other legume crops (Alexander, 1978) in temperate regions. For conditions in the humid tropics, there is very little information regarding the factors determining the quantity of N fixed by any particular legume - *Rhizobium* symbiosis.

Grain legumes form a major component of tropical agriculture. They are bestowed with an ability to grow in depleted soils and may at times contribute a modicum of fertility to the succeeding crops through their unique symbiotic compatability with nitrogen fixing *Rhizobium* sp. The input of soil nitrogen from grain legumes is limited as they are grown only over a comparatively smaller area than the cereals.

In Kerala, pulses are cultivated in about 37,000 hectares during Kharif, Rabi and Summer seasons. Cowpea (*Vigna unguiculata*) is a very popular pulse variety cultivated in Kerala in all the three seasons over comparatively larger areas in the uplands as well as in fallow paddy fields in summer. It is used both as a vegetable and grain.

The actual benefit derived from the cultivation of cowpea or any other legume in terms of the fixation of nitrogen and increase in the content of soil nitrogen may depend on several other factors such as period of growth of the crop, extent of incorporation and subsequent mineralisation in the soil aswell as on the initial nitrogen status of the soil as has been emphasised by several workers (Vincent, 1965; Jones, 1972; Henzell and Vallis, 1975). Hence the residual benefit imparted by a leguminous crop to the succeeding plants also will depend on the above factors. A major fraction of the nitrogen fixed by the legume is stored in the different plant parts and the rest is known to be excreted into the soil. It may be reused by the legume itself at a later stage under monoculture or by the companion crop or crops in a mixed cropping system.

In devising and developing such systems which make substantial addition to the nitrogen economy of soil, it is important to take into account the actual estimates of nitrogen contribution made by the legume - Rhizobium symbiosis under various situations.

Since the amount of nitrogen taken up and excreted into the soil is known to vary at different stages of growth of a legume plant, it is imperative to make a quantitative assessment of these factors at the prescribed stages. It is justifiable that once these factors are identified and better understood, considerable improvement in the magnitude of nitrogen fixation perhaps could be manipulated.

Keeping these ideas in view, the present investigation was taken up with the main objectives of

(i) Estimating the quantity of nitrogen fixed by cowpea (Vigna unguiculata) at three different stages of its growth corresponding to the periods when it may be utilised as a fodder/green manure, vegetable and grain.

(ii) Quantifying the effect of residual soil nitrogen on a succeeding crop of fodder maize.

A study of the uptake and utilisation of phosphorus, potassium, calcium and magnesium in comparison to nitrogen at the different stages of growth of cowpea was also envisaged.

The results obtained from the study may prove helpful in a better understanding of the rate and extent of fixation and utilisation of nitrogen by cowpea and legumes in general.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Grain legumes form a major component of the cropping system in tropical agriculture. They are important in their ability to fix atmospheric nitrogen and to conserve the limited supply of this element in the soil, besides providing a source of protein rich food grain. A brief review of the scientific literature on the contribution of legumes in the maintenance of soil nitrogen under different utilization systems and their residual effect on succeeding crops is given below.

1. Nitrogen enrichment of soil by legumes

Hartwell and Pember (1911) reported a gain of nearly one ton of soil nitrogen per acre from the results of pot culture experiments where cowpea and soybean were grown for a period of five years.

Sen and Rao (1953) reported that 251 kg of nitrogen was fixed annually per hectare by the action of symbiotic nitrogen fixing bacteria in association with legumes under most favourable conditions.

Buckman and Brady (1960), while estimating the quantity of nitrogen added to the soil by a crop of red clover reported the figures as ranging from 100 to 150 kg nitrogen per hectare.

Nutman (1971) estimated the fixation of nitrogen by cowpea as 73 to 240 kg per hectare per annum.

Agboola and Fayemi (1972) in an investigation showed that calapagonium, cowpea and greengram fixed nitrogen at the rate of 450, 354 and 324 kg per hectare respectively when grown in a complete nutrient culture devoid of nitrogen as compared to 370, 157 and 63 kg nitrogen per hectare respectively when they were grown in a unfertilized soil.

Sahu and Behera (1972) observed that cultivation of cowpea, groundnut and greengram increased the nitrogen content of soil.

Vincent (1974) has reported a high nitrogen fixation rate of the order of 550 kg N per hectare per annum in peas.

Goswami and Pareek (1976) from field studies reported that 256 kg N per hectare could be fixed by soybean.

Alexander (1978) reported that the quantity of nitrogen fixed symbiotically by cowpea ranges from 65 to 130 kg per hectare per year.

Englesham (1981), in a field trial with different varieties of cowpea reported nitrogen fixation rates as ranging from 49 to 101 kg per hectare.

The actual benefit in terms of the fixation of atmospheric nitrogen and the gain in soil nitrogen content has been found to depend on several factors such as the period of growth of the legume crop, whether it is being incorporated into the soil or not and also the nutrient status of the soil, especially nitrogen.

Fellers (1918), after intensively studying the effect of growing alfalfa continuously for a long period, reported that it only depleted the soil nitrogen when compared to a soil that was left under sod.

In another s tudy Greaves and Jones (1950) based on the strength of a 16 year old study on alfalfa gave support to the view that the removal of the crop after harvest did not significantly increase the nitrogen status of the soil whereas returning the crop to the soil significantly increased the soil nitrogen content.

Thompson (1952) considered that the amount of nitrogen added to the soil by a legume depended upon its age, photosynthetic rate and presence or absence of combined nitrogen in the soil.

Waksman (1952) reported that if a legume crop is harvested and r emoved from the soil, the amount of nitrogen added to the soil through its cultivation might be negligible since the amount of nitrogen assimilated from the atmosphere is mostly present in the tops.

Mirchandani and Khan (1953) found that the amount of nitrogen fixed by a legume depended upon its age, condition of growth and stage of ploughing in. They suggested that the amount of nitrogen in a leguminous plant is the sum total of nitrogen it has obtained from the air and soil. They fixed it as two thirds from the air and one third from the soil.

Russell (1961) has reported that legumes may not increase the soil nitrogen content under all conditions. In the case of well nodulated legumes like peas, beans, soy-beans and grounds, a large proportion of the nitrogen fixed is removed during harvest.

Black (1968) has expressed the view that there is a decrease in the fixation of atmospheric nitrogen as the nitrogen supply in the soil is increased.

Henzell and Vallis (1975) found that where grain or forage is harvested, as much as 60 to 90 per cent of the legume nitrogen may be removed from the land. He emphasised the fact that the amount of nitrogen removal will be further enhanced if the plant tops are harvested as green forage or hay or when the whole plant is removed for threshing.

In a field experiment to compare the nitrogen fixation by four cowpea varieties and two soybean cultivars in the presence of different levels of applied nitrogen, Englesham et al. (1982) found that generally soybean fixed more nitrogen than cowpea.

Englesham et al. (1983) observed a synergistic effect in soybean between applied nitrogen and nitrogen fixation especially with urea application at 30 mg N per pot. He found that for every mg of urea nitrogen absorbed, an additional quantity of 15 mg N was fixed by the plant.

2. Effect of Rhizobium inoculation on yield and nitrogen fixation in cowpea

Katti et al. (1970) found that Rhizobium inoculation of soybean increased the yield of the succeeding crop of wheat and ragi.

Rotimi (1970) found that inoculation of cowpea with Rhizobium increased the number of effective nodules, plant dry matter and nitrogen content of the tissues.

Chatterjee et al. (1972) observed that the variations in the amount of nitrogen fixed by different legumes are due to the differences in the Rhizobium strain associated with them.

Deshmukh and Joshi (1973) found that inoculation of cowpea with Rhizobia increased the yield of dry matter and crude protein content. It was also seen that the inoculated plots yielded more than 400 kg of protein per hectare.

Lapinskas (1973) found that the nitrogen requirement of bean plants was satisfied better by the nitrogen fixed by *Rhizobia* than by the application of large amounts of mineral nitrogen.

Sahu (1973) reported that *Rhizobium* inoculation alone could enhance the nitrogen content of the soil by 20 to 38 per cent in the case of bengalgram and by 7 to 19 per cent in the case of horsegram.

Goswami and Pareek (1976) from field studies have shown profuse nodulation in soybean following inoculation with five strains of *Rhizobium japonicum* which subsequently gave upto 135 per cent increase in yields.

From an experiment conducted under the I.C.A.R. Co-ordinated scheme on "Micronutrients in plants and soils", it has been reported that inoculation of bengalgram varieties with *Rhizobium* strains helped to increase the available nitrogen status of the soil (Anonymous, 1978).

Zary et al. (1978) observed significant differences in the efficiency of nitrogen fixation in pulses following the application of standard commercial mixed strain *Rhizobium* inoculant.

Keyser et al. (1979) in a glass house trial on the symbiotic effectiveness of *Rhizobia* and its ability to nodulate *Vigna unguiculata* reported that while shoot nitrogen content varied from 120 to 140 mg per plant with good nodulation it ranged from 5 to 7 mg per plant only with poor nodulation.

Mughogho (1979) reported that the mean nitrogen yields in soybeans ranged from 40.6 to 63.5 kg per hectare and in cowpea from 12.9 to 17.1 kg per hectare after inoculation with Rhizobium.

Rao (1980) reported an increase in grain/seed yield resulting from the inoculation of legume seeds with Rhizobium strains.

Srivastava and Tewari (1981) observed that most of the strains of Rhizobia caused an increase in the nitrogen content in cowpea and greengram.

3. Nodulation in cowpea at different stages

Dart and Wildon (1970) observed that primary root nodulation of cowpea was stimulated by a low nitrogen content of the soil, while it was inhibited by a high nitrogen level in the soil.

Summerfield et al. (1975) suggested that effectively nodulated cowpea would produce very high seed yield under tropical conditions without nitrogen fertilizer application.

Swaraj and Garg (1977) from studies on the effects of aging of the host and senescence of the nodules on the content and composition of the proteins of leghaemoglobin in cowpea observed that the haemprotein content was highest in red nodules and it decreased with the onset of nodule senescence. In fully senescent green nodules, the total protein decreased to a very low level while haemproteins were absent.

Minchin et al. (1981) reported that providing inorganic nitrogen during the vegetative period stimulated nodulation and nitrogenase activity. Plants were more leafy and produced a larger number of potential reproductive sites (nodes) and higher seed yields.

Nerves et al. (1981) in a study on carbon and nitrogen nutrition of cowpea found that plants dependent on nitrate were much more efficient during the vegetative period than those relying on nodules.

Zablotowicz (1981) observed a maximum nodule weight of 175 mg per plant at the flowering stage.

Englesham et al. (1982) reported that the weight of nodules in cowpea was maximum at the early pod fill stage when the level of soil nitrogen was low. With a high nitrogen content in the soil, maximum weight of nodules was obtained at late pod fill stage.

4. <u>Mobilisation of nitrogen in plants at different stages</u>

Substantial quantities of nutrients, primarily nitrogen were translocated from the vegetative plant parts to the developing seeds during pod filling in soybean (Ohlrogge, 1960).

Russell (1961) reported that the entire nitrogen fixed by a legume plant is transferred to tops and seeds as it matures.

Jacquinot (1967) showed that nitrogenous substances are concentrated in leaves during the vegetative period and transported to the seeds during grain filling period.

In trials with cowpea, Singh and Jain (1968) found that the nitrogen and phosphorus contents of plants decreased with age upto the stage of harvest.

According to Hanway and Weber (1971 a) approximately half of the nitrogen in mature pods was translocated from other plant parts.

Agboola and Fayemi (1972) reported that cowpea (Vigna unguiculata), greengram (Vigna radiata) and calapagonium (Calapagonium muconoides) can accumulate nitrogen in their tissues at rates more than 300 kg per hectare in a period of 12 to 14 weeks.

In a study using acetylene reduction method for the estimation of nitrogen fixation in several grain legumes it was found that cowpea fixed the maximum amount of atmospheric nitrogen during its vegetative stages. During the reproductive stage, soybean fixed more nitrogen than cowpea (Anonymous, 1973).

The amount of nitrogen fixed by varieties of cowpea decreased markedly after flowering stage and mung bean fixed very little nitrogen because of poor nodulation and crop stand (Anonymous, 1974).

According to Pal and Saxena (1976), the nitrogen concentration in the stem, leaves and petioles decreased with plant age. The nitrogen concentration in pods increased with age due to continued nitrogen assimilation and translocation from vegetative plant parts. The accumulation of nitrogen in vegetative plant parts followed a sigmoid pattern with plant development while in the pods it linearly increased. The rate of nitrogen accumulation was maximum during pod filling stage.

Sinclair and Dewit (1976) suggested that during seed filling stage nitrogen must be translocated from vegetative tissues to seeds and half the nitrogen present in the seed might be derived from the vegetative tissues.

Borges (1977) reported that while the major proportion of the atmospheric nitrogen fixed was located in the roots 82 per cent of the total nitrogen in the plant was present in the above ground parts.

According to Englesham et al. (1977) symbiotic fixation significantly contributed to the total nitrogen content of the plant during early growth period and to the seed nitrogen content during the late pod filling stage.

Farrington et al. (1977) indicated a rapid mobilisation of nitrogen from the vegetative components to the seed during seed filling in lupine at a time when the nitrogen fixation had ceased.

During seed filling in cowpea, all vegetative parts lost nitrogen and mobilisation of nitrogen occurred from the leaflets (Herridge and Pate, 1977).

Hocking and Pate (1977) observed that 60 to 90 per cent of the nitrogen was transferred from the leaves of peas and lupine during their fruiting periods.

Summerfield et al. (1977) reported that concentration of stem and leaf nitrogen in cowpea plants generally increased by nodulation and with various levels of applied nitrogen. Atleast 95 per cent of the plant nitrogen was present in the seed.

Derman et al. (1978) indicated a clear redistribution of nitrogen from leaves to the seeds in soybean.

According to Minchin and Summerfield (1978), nitrogen accumulated after flowering was translocated to post flowering vegetative and reproductive components.

Pulver and Wien (1978) found that cowpea accumulated 43 per cent of its Total Reduced Nitrogen (TRN) in the pre-flowering stage. Maximum rate of TRN was observed at flowering and decreased rapidly during pod development. The point at which nitrogen demand exceeded the nitrogen supply coincided with leaf senescence, indicating that the nitrogen demand was being fulfilled by redistribution of nitrogen from other plant organs. Most of the TRN produced during pod filling was translocated directly to the seed.

Williams (1979) reported that nitrogen present in leaves and stems of groundnut started to decline shortly after the start of reproductive growth.

Huxley (1980) estimated that 40 to 50 per cent of stored nitrogen moved from the structural parts to the seeds in cowpea.

5. <u>Excretion of nitrogen by cowpea</u>

According to Wallace (1937) there is transfer of nitrogen from the legumes to the non legumes when they are grown together. However, Wilson and Wyss (1938) obtained no evidence for exudation of nitrogen from legumes grown in association with the non legumes. They suggested that exudation of fixed nitrogen from the leguminous plants grown in the field might be expected to occur in regions where weather during growing season is cool and cloudy.

Buckman and Brady (1960) reported that part of the nitrogen fixed by legume may pass into the soil itself either by excretion or more probably by sloughing of the roots and nodules.

Evidence of substantial excretion of nitrogen by legume roots has been furnished by Virtanen and Mietinen (1963). Their results clearly indicate that the rate of excretion is maximum before and at the beginning of flowering when the nodules are still young and fully active without even a sign of degeneration.

In greenhouse experiments, Whitney and Kanehiro (1967) found that nitrogen is transferred from the legume to the soil by excretion from roots, by leaching from the leaf surfaces and by the decay of leaves, roots and nodules.

Henzell and Vallis (1975) suggested that the concentration of nitrogen in the legume residues varies widely and has a major influence on the transfer. The initial flush of mineralization from legume residues which provides most of the transfer is related directly to the percentage of nitrogen in these residues and to the quantity of these residues.

The beneficial effect of mixed cropping is often attributed to the excretion of nitrogen by legumes, the roots actively liberating nitrogen obtained from the atmosphere (Alexander, 1978). He has also suggested that only small amounts of nitrogen was released by legume roots and only a portion of the nitrogen needed by adjacent plants can be provided by this mechanism.

Mathan et al. (1979) concluded that a considerable quantity of the nitrogen fixed by the legume has been redistributed in the soil depending on the fertility status of the soil.

Varghese (1982) has reported a decrease in the total nitrogen content of the soil at the maximum flowering stage of cowpea which was later made up by the excretion of nitrogen into the soil.

6. Residual nitrogen and its effect on a succeeding crop

Hyden et al. (1957) observed that four years of growing Kudzuvine in Mississipi gave an average increase of 43 per cent more of soil nitrogen compared to fields where corn was cropped continuously for four years. They have stated that the cultivation of legume preceding a cotton crop was equivalent to the application of 24 kg of commercial nitrogen to the corn crop.

Nair et al. (1957) while investigating the nitrogen balance in laterite soils of Pattambi by growing *Sesbania speciosa* failed to get any significant increase in soil nitrogen.

Buckman and Brady (1960) reported that when a legume is turned under some of the nitrogen become available to the succeeding crop. They pointed out that the nitrogen content of the soil will show a decrease when the soil has a high nitrogen content or when the tops are harvested and removed from the land.

Russell (1961) has reported that legumes may not increase the soil nitrogen under all conditions.

Agboola and Fayemi (1972) suggested that legumes are incapable of benefitting associated non legumes during the same growing period. They also found that the legumes fix more nitrogen when interplanted with corn than when grown alone.

Henzell and Vallis (1975) were of the view that there is not much economic justification for growing legumes solely as green manures. The most effective release of mineral nitrogen for use by other crops occurs when legume residues with a high content of nitrogen decompose in the soil. It has been noted that the nitrogen in decaying legume residues after the initial flush of mineralisation is made available at a slower rate.

Saxena and Tilak (1975) found that the yield of wheat following inoculated soybean was increased by 65 per cent over that following an uninoculated soybean crop.

Goswami and Pareek (1976) have reported an increase of 5 - 7 quintals in the yield of wheat following an inoculated crop of soybean.

Singh and Singh (1976) observed that kharif legumes significantly increased the grain yield of subsequent wheat compared to the control fields which were kept fallow or planted to sorghum fodder. They also emphasised that the effect of different grain and forage legumes was not similar in terms of their legume effect.

In the experiment conducted under the I.C.A.R. Co-ordinated scheme on "Micronutrients in plants and soils" an increase in the content of the available nitrogen status was obtained by cultivating bengalgram after inoculating with Rhizobia strain (Anonymous, 1978).

Residual nitrogen effect to the tune of 60 kg N per hectare for cowpea has been reported by Giri and De (1979) under Indian conditions.

Mathan et al. (1979) reported that when a leguminous crop like cowpea was included in a rotation of maize cg. Ganga 5, the total nitrogen content of the soil was considerably increased even in the unfertilized plots.

Rao (1979) considered that legumes leave behind some amount of nitrogen in the soil. He has stated that the residual effect of growing legumes could be judged by the yield of a subsequent crop of wheat or rice.

Sprent (1979) found that the nitrogen fixed during vegetative growth of legumes may remain in the soil and become available to the subsequent crop. He emphasised that nitrogen left over by the roots and nodules of soybean may contribute an equivalent of 20 kg N per hectare to a subsequent crop of rye.

Residual nitrogen effect to the tune of 40 kg nitrogen per hectare has been reported by Kumar Rao and Dart (1980) for pigeon pea under Indian conditions.

Mughogho et al. (1981) have reported that the yield of a subsequent maize crop was increased by the incorporation of cowpea residues which made available the equivalent of 40 to 80 kg fertilizer nitrogen per hectare.

Varghese (1982), based on the results of a pot culture experiment has emphasised the need for the incorporation of tops and haulm into the site of cultivation itself to ensure a substantial residual effect of nitrogen for the succeeding crops. He has also reported a variation in the residual effect depending on the stage of harvest of the crop.

MATERIALS AND METHODS

MATERIALS AND METHODS

An investigation was carried out with the main objective of estimating the nitrogen fixed by cowpea at different stages of growth, corresponding to varying periods in its use as a fodder/green manure, vegetable and grain. The residual effect of nitrogen in the soil at the three stages was studied by raising a succeeding crop of fodder maize.

A. Field Experiment

1. Experimental site and soil

The field experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during the kharif season of 1982-83. The soil in the experimental field was analysed for its nutrient status and the results are given in Table 1.

2. Design and treatments

The experiment was conducted in two parts in succession in the same field.

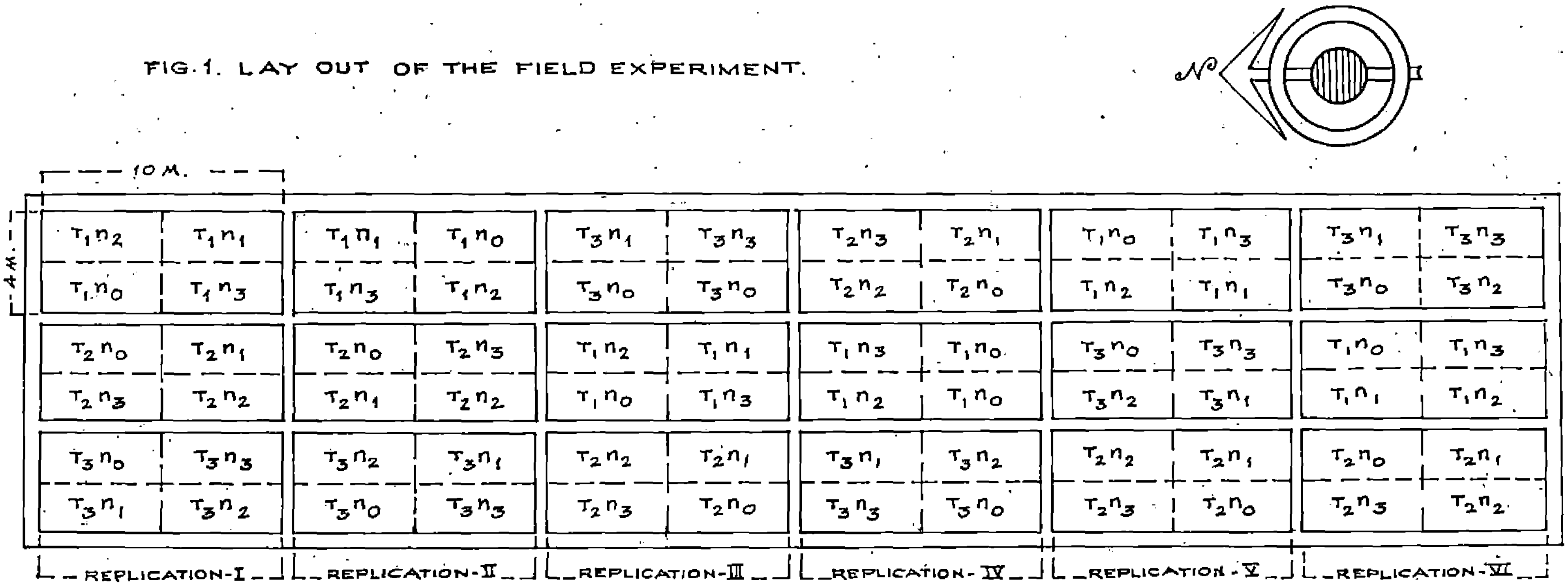
Experiment I

The first part of the experiment was laid out as Randomised Block Design with three treatments and six replications. The plan of the experiment is shown in Fig.1 and the details of the layout are given below.

Table 1. Nutrient status of the soil in the experimental field.

Total nitrogen	-	0.050 per cent
Available nitrogen	-	271 kg/ha
Available phosphorus	-	32 kg/ha
Exchangeable potassium	-	100 kg/ha
Exchangeable calcium	-	1.15 me/100 g soil
Exchangeable magnesium	-	0.28 me/100 g soil

FIG. 1. LAY OUT OF THE FIELD EXPERIMENT.



TREATMENTS.

MAIN PLOT

T_1 - COWPEA HARVESTED AT MAXIMUM FLOWERING STAGE

T_2 - COWPEA HARVESTED AT MID POD FILLING STAGE

T_3 - COWPEA HARVESTED AT MATURITY STAGE

SUB PLOT

n_0 - NO NITROGEN APPLIED (HARVESTED TOPS NOT INCORPORATED)

n_1 - NO NITROGEN APPLIED (HARVESTED TOPS INCORPORATED)

n_2 - NITROGEN APPLIED AT 30 kg/ha (HARVESTED TOPS NOT INCORPORATED)

n_3 - NITROGEN APPLIED AT 60 kg/ha (HARVESTED TOPS NOT INCORPORATED)

Treatments

T_1 - Cowpea harvested at maximum flowering stage.

T_2 - Cowpea harvested at mid pod filling stage.

T_3 - Cowpea harvested at maturity stage.

Spacing - 25 x 15 cm

Size of the plot

Gross plot - 4 x 10 m

Net plot - 3.2 x 9.4 m

Total number of plots - 18

3. Experimental procedure

The experimental area was dug, cleared of weeds, levelled and divided out into blocks and plots.

Burnt lime was applied in the soil two weeks prior to the sowing of cowpea seeds at the rate of 250 kg per hectare. Fertilizers as per the Package of Practices Recommendations of the Kerala Agricultural University (1982) were applied in the plots on the day before sowing.

The dates of sowing of cowpea seeds for the three treatments were staggered in such a manner that the date of harvest of the plants from the different treatments was on the same day (2-10-1983). Seeds of cowpea var. Kanakamani, after treatment with *Rhizobium* culture were sown on the following dates for the three treatments.

Cowpea harvested at maturity stage (T_3) - 22-7-1983

Cowpea harvested at midpod filling stage (T_2) - 6-8-1983

Cowpea harvested at maximum flowering stage (T_1) - 16-8-1983

Irrigation was given once in two days in the initial stages and later once in a week. The thinning and inter-cultural operations were done two weeks after sowing.

Carbaryl (Sevin) was sprayed to control the flower and pod borer during the flowering period.

The pods in the treatment T_2 were harvested as and when they reached the vegetable stage. The weight of the pods in the different pickings were recorded and pooled together. Similarly the mature pods in the treatment T_3 were harvested as and when they matured and the total weight was recorded. The weight of grain as well as pod wall were determined separately. Samples of vegetable pods, grain and pod wall were dried in an air oven at 70°C and stored in labelled envelopes for chemical analysis.

Four plants were selected at random from each plot for the different treatments and the height of the plants was measured from the base to the tip of the topmost leaf. The field was put under irrigation and the selected plants were carefully lifted on the following day with the help of a spade taking care to see that dislodging of nodules and damage to the root system did not take place. The roots were washed free of adhering soil with a slow jet of water through a hose. The root nodules from each plant were separately collected, counted and the fresh weight was recorded. The weight of the entire plants was then taken and kept apart for further chemical analysis after drying in an air oven at 70°C. The remaining plants from each plot were also lifted out, the adhering soil particles removed and the total fresh and dry weight recorded.

The soil in each plot was mixed well and representative samples were collected in polythene bags. The soil was air dried, powdered, sieved and stored in sealed bottles for chemical analysis.

Experiment II

The experiment to study the residual effect of nitrogen on a succeeding crop was laid out as split plot design with six replications. The plots in Experiment I with the different treatments (T_1, T_2 and T_3) were divided into four sub plots each, receiving the following treatments.

n_0 - No nitrogen applied (harvested tops not incorporated)

n_1 - No nitrogen applied (harvested tops incorporated)

n_2 - Nitrogen applied at 30 kg/ha (harvested tops not incorporated)

n_3 - Nitrogen applied at 60 kg/ha (harvested tops not incorporated)

Treatment combinations

T_1n_0	T_2n_0	T_3n_0
T_1n_1	T_2n_1	T_3n_1
T_1n_2	T_2n_2	T_3n_2
T_1n_3	T_2n_3	T_3n_3

The individual plots were dug and the harvested tops of the cowpea crop were chopped and incorporated into the soil by thorough mixing in plots receiving the treatment n_1. These plots were watered once in two days to permit the proper decomposition of the added crop residues. After two weeks, fertilizers except nitrogen were applied to all these plots as per recommendations in the Package of Practices (1982) for fodder maize. Nitrogen at the rate of 30 and 60 kg per hectare was appliedd as urea in plots receiving the treatments n_2 and n_3 respectively. All the plots were levelled properly and soil samples were collected for analysis before the sowing.

Sowing of the maize seeds in the different plots was done on 23-10-1983 at a spacing of 30 x 15 cm. Seedling emergence was completed in 5 to 6 days. Thinning was done to retain two plants per hill on 4-11-1983.

Irrigation was given daily in the initial stages and later once in two days till flowering. Hand weeding was done to clear off weeds. The crop was harvested in bulk on 27-12-1983, when it reached the milky stage.

Four plants at random were selected from each plot and their height and weight were recorded. They were chopped, dried in an air oven at 70°C in labelled envelopes and kept for chemical analysis. The remaining plants from each plot were also harvested and their fresh and dry weight recorded.

The soil in each plot was mixed well and representative samples were collected in polythene bags. The soil samples were air dried, powdered, sieved and stored in closed bottles for further chemical analysis.

B. Chemical Analysis

a. Soil

The soil samples collected from the different plots before the starting and after the completion of the two experiments were analysed for the following.

Total nitrogen

Total nitrogen in the soil was estimated by modified micro-kjeldahl method as described by Jackson (1967).

Available nitrogen

Available nitrogen was estimated by the alkaline permanganate method suggested by Subbiah and Asija (1956).

Available phosphorus

Available phosphorus content in the soil was estimated by Bray's extractant No.1 (Jackson, 1967). The colour intensity was read in a Klett-Summerson Photoelectric Colorimeter.

Available potassium

Available potassium was extracted by ammonium acetate (Jackson, 1967) and determined by the flame emission of an

EEL Flame Photometer.

Exchangeable calcium and magnesium

Exchangeable calcium and magnesium were estimated from ammonium acetate leachate using Atomic Absorption spectrophotometer.

b. Plant

Oven dry samples of plants collected from the two field experiments were homogenised and analysed for its nutrient composition by standard chemical methods as outlined by Jackson, 1967.

From these values the total uptake of nitrogen as well as phosphorus, potassium, calcium and magnesium in the different plant samples was calculated.

c. Nitrogen balance

Nitrogen balance was calculated at each stage of growth of cowpea from the following expression.

Nitrogen balance = (Total N in dry matter + N in the soil at specific stage)-(N in seeds sown + N in soil before sowing)

as worked out by Dart and Wani (1982).

D. Statistical Analysis

Data relating to the different observations of the two experiments were statistically analysed using analysis of variance technique for RBD and split plot design and significance was tested by F test (Snedecor and Cochran, 1967).

RESULTS

RESULTS

The results of the experiment to find out the nitrogen fixation by cowpea as influenced by the stage of growth and duration of the crop and its residual effect on a succeeding crop of fodder maize are presented in this chapter.

1. Nitrogen fixation by cowpea at different stages of growth

a) Growth and nodulation pattern

The mean values of the height of the plant, number and fresh weight of nodules, fresh weight of tops and total dry matter yield at the time of harvest corresponding to the different stages of growth of cowpea are presented in Table 2 and the analysis of variance in Appendix I.

Height of the plant

The average height of the plant corresponding to maximum flowering stage, mid pod filling stage and maturity stage showed an increasing trend towards maturity. Though there is apparent difference between the height of the plant at mid pod filling and maturity stages, they are statistically not different. The height of plant was 47, 54 and 56 cm respectively at the maximum flowering, mid pod filling and maturity stage of the crop.

Table 2. Growth and nodulation pattern of cowpea at different stages of harvest.

Treatments / Mean	Height of the plant cm	Number of nodules	Weight of nodules g	Fresh weight of tops kg/plot	Dry matter production kg/plot
(1)	(2)	(3)	(4)	(5)	(6)
Maximum flowering stage (T_1)	47	24	0.51	26.6	16.4
Mid pod filling (T_2)	54	20	0.39	34.3	21.3
Maturity stage (T_3)	56	14	0.32	41.6	28.6
C.D.	7	2	0.09	2.0	0.9

Number and weight of nodules

It is seen that the stage of the crop has significantly influenced the number of nodules per plant. Nodule number is highest at maximum flowering stage and it decreases as the crop attains maturity. The number of nodules was 24, 20 and 14 at the maximum flowering, mid pod filling and maturity stages of the crop respectively.

The fresh weight of nodules is observed to be highest at the maximum flowering stage (0.51 g). The value decreased to 0.40 g at the mid pod filling stage and to 0.32 g at the maturity stage. The weight of the nodules at maximum flowering stage was found to be higher than that at the other two stages of growth of the plant. Though there is an apparent difference between the fresh weight of nodules at mid pod filling stage and maturity stages, they are statistically on par.

Fresh weight of stem and leaves

Significant differences between the fresh weight of stems and leaves harvested at different stages are observed. The weight showed a sharp increase with increase in the age of the crop. Thus, maximum fresh weight of 41.6 kg per plot is obtained for cowpea at the maturity stage followed by the plants at the mid pod filling (34.3 kg) and maximum flowering stages (26.6 kg).

Dry matter yield per plot

The total dry matter yield including the weight of pods and root obtained from the plants at different stages of growth also showed an increasing trend from the maximum flowering stage upto the maturity stage. Dry matter yield corresponding to the maximum flowering, mid pod filling and maturity stage were 16.4, 21.3 and 28.6 kg per plot respectively.

b) <u>Nutrient content and total uptake of nutrients</u>

The mean values of the content of nitrogen, phosphorus, potassium, calcium and magnesium in different plant parts and the total uptake of these nutrients at different stages of growth of cowpea are presented in Tables 3 a, b, c, d and e. The analysis of variance is given in Appendix II, III and IV.

Nitrogen

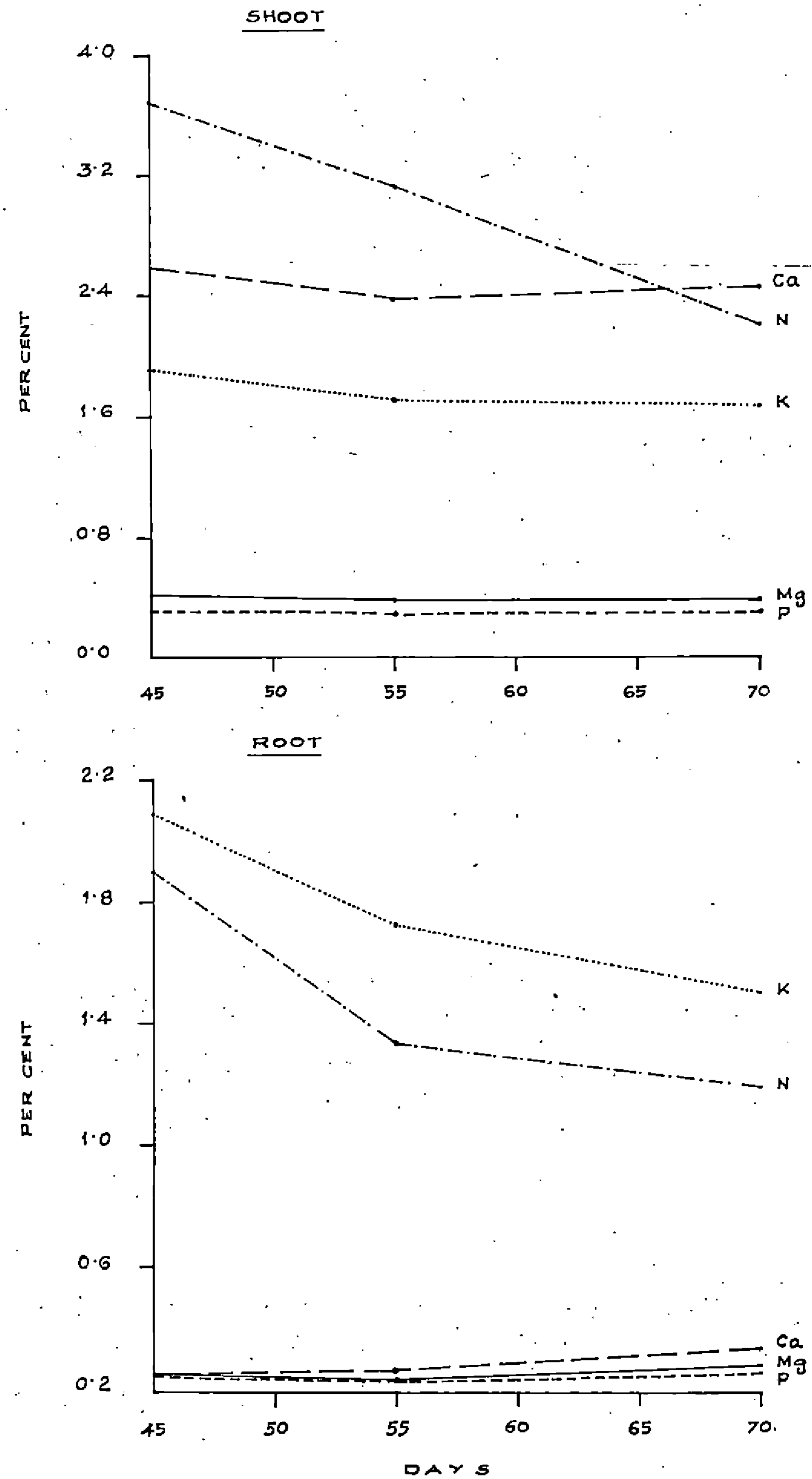
The content of nitrogen in the stems and leaves was found to be highest at the maximum flowering stage of cowpea. It recorded a value of 3.67 per cent which decreased to 3.14 per cent at the mid pod filling stage and to 2.19 per cent at the maturity stage. The decrease in the nitrogen content between the different stages is highly significant and a reduction of about 14 and 40 per cent in the nitrogen content was noticed between maximum flowering and mid pod filling as well as between

Table 3 a. Nitrogen content and total uptake at different stages of growth of cowpea.

Mean	Maximum flowering stage			Mid pod filling stage			Maturity stage		
Plant parts	Dry weight kg/plot	Ber cent nitrogen	Nitrogen uptake g/plot	Dry weight kg/plot	Per cent nitrogen	Nitrogen uptake g/plot	Dry weight kg/plot	Per cent nitrogen	Nitrogen uptake g/plot
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Stem and leaves	15.3	3.67	560	17.5	3.14	545	23.0	2.19	502
Roots	1.1	1.90	19	1.2	1.33	17	1.1	1.19	13
Vegetable pods	-	-	-	2.6	1.43	37	-	-	-
Grain	-	-	-	-	-	-	3.6	3.71	134
Pod wall	-	-	-	-	-	-	0.9	0.90	8
Total	16.4	-	579	21.3	-	599	28.6	-	657

C.D. for nitrogen content in shoot - 0.20
C.D. for nitrogen content in root - 0.28
C.D. for total nitrogen uptake - 32

FIG. 2. NUTRIENT STATUS IN SHOOT AND ROOT AT DIFFERENT STAGES OF GROWTH OF COW PEA.



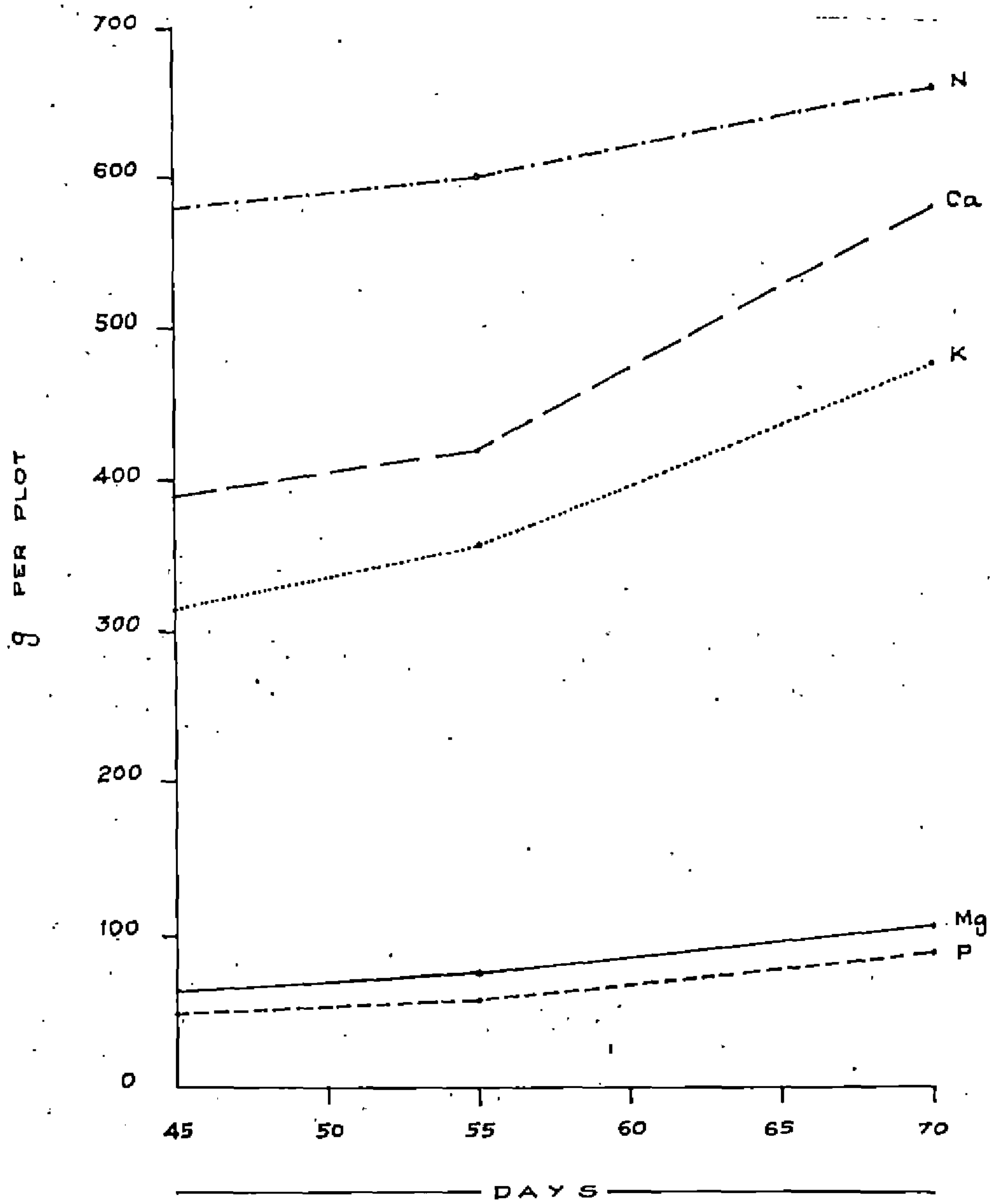
maximum flowering and maturity stages respectively.

In the case of roots also the content of nitrogen was highest at maximum flowering stage (1.90 per cent) followed by mid pod filling (1.33 per cent) and maturity stage (1.19 per cent). About 30 per cent reduction in the nitrogen content of roots was noticed from maximum flowering stage to mid pod filling stage and about 37 per cent reduction from maximum flowering to the maturity stage. The difference in the nitrogen content in the root at different stages was found to be significant.

The content of nitrogen in the vegetable pods was 1.43 per cent and that of the mature grain was 3.71 per cent. The pod walls recorded a nitrogen content of 0.90 per cent.

The total uptake of nitrogen on a whole plant basis showed an increasing trend from the maximum flowering to the maturity stage. The total nitrogen uptake amounted to a value of 657 g per plot at maturity stage followed by 599 g at mid pod filling stage and 579 g at the maximum flowering stage. The difference in the total uptake of nitrogen was significant between the maturity stage and the mid pod filling stage and between the maturity and maximum flowering stage. Though there is apparent difference in the total uptake between the maximum flowering and the mid pod filling stage, the difference was not statistically significant.

FIG.3. UPTAKE OF NUTRIENTS IN COW PEA AT DIFFERENT STAGES OF GROWTH



Phosphorus

The content of phosphorus in the stem and leaves was highest (0.30 per cent) at the maximum flowering stage. The value decreased to 0.27 per cent at the mid pod filling and recorded a slight increase when the crop reached the maturity stage where the phosphorus content was 0.31 per cent. However, the difference in the content of phosphorus between the different stages of growth of the plant was not significant.

The content of phosphorus in the roots was 0.25, 0.24 and 0.26 per cent respectively at the maximum flowering, mid pod filling and maturity stage, recording only marginal difference between the stages.

The phosphorus content of the vegetable pods was 0.22 per cent, that of the grain 0.34 per cent and of the pod wall 0.07 per cent.

As in the case of the total uptake of nitrogen, the total uptake of phosphorus also showed an increasing trend towards the maturity stage of the crop. The total uptake of phosphorus at the maximum flowering stage was 49 g per plot which increased to 57 g per plot at the mid pod filling and to 88 g per plot at the maturity stage of the crop. Uptake was found to be highest at the maturity stage and was superior to the values at the mid pod filling and the maximum flowering stages. No statistical difference in the uptake of phosphorus between the mid pod filling and

Table 3 b. Phosphorus content and total uptake at different stages of growth of cowpea.

Mean / Plant parts	Maximum flowering stage			Mid pod filling stage			Maturity stage		
	Dry weight kg/plot	Per cent phosphorus	Phosphorus uptake g/plot	Dry weight kg/plot	Per cent phosphorus	Phosphorus uptake g/plot	Dry weight kg/plot	Per cent phosphorus	Phosphorus uptake g/plot
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Stem and leaves	15.3	0.30	46	17.5	0.27	48	23.0	0.31	72
Roots	1.1	0.25	3	1.2	0.24	3	1.1	0.26	3
Vegetable pods	-	-	-	2.6	0.22	6	-	-	-
Grain	-	-	-	-	-	-	3.6	0.34	12
Pod wall	-	-	-	-	-	-	0.9	0.07	1
Total	16.4	-	49	21.3	-	57	28.6	-	88

S.E. for phosphorus content of shoot - 0.02

S.E. for phosphorus content of root - 0.02

C.D. for total phosphorus uptake - 9

S.E. for total phosphorus uptake - 4

the maximum flowering stage could be observed.

N/P ratio

The mean value of the N/P ratio presented in Table 4 and Appendix IV is found to be highest at the maximum flowering stage when it recorded a value of 12.2. The value then decreased to 11.0 at the mid pod filling stage and to 7.8 at the maturity stage. The decrease in the ratio from the maximum flowering to mid pod filling stage was not statistically significant while that from the maximum flowering to maturity stage and from the mid pod filling stage to maturity was highly significant.

Potassium

At the maximum flowering stage, the stems and leaves recorded a value of 1.90 per cent potassium which decreased to 1.70 per cent at the mid pod filling stage. At the maturity stage it again decreased to 1.65 per cent. A reduction of about 10.5 and 13 per cent in the content of potassium was observed at the mid pod filling and the maturity stages compared to the maximum flowering stage. However, the reduction from the maximum flowering to the mid pod filling stage and from the mid pod filling to the maturity stage was not significant and the decrease was only marginal.

The content of potassium in the roots also showed a decreasing trend from the maximum flowering to the maturity

Table 3 c. Potassium content and total uptake at different stages of growth of cowpea.

Mean Plant parts	Maximum flowering stage			Mid pod filling stage			Maturity stage		
	Dry weight kg/plot	per cent potassium	Potassium uptake g/plot	Dry weight kg/plot	Per cent potassium	Potassium uptake g/plot	Dry weight kg/plot	Per cent potassium	Potassium uptake g/plot
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Stem and leaves	15.3	1.90	294	17.5	1.70	296	23.0	1.65	378
Roots	1.1	2.08	22	1.2	1.72	21	1.1	1.50	17
Vegetable pods	-	-	-	2.6	1.50	39	-	-	-
Grain	-	-	-	-	-	-	3.6	1.87	67
Pod wall	-	-	-	-	-	-	0.9	1.07	90
Total	16.4	-	316	21.3	-	356	28.6	-	472

S.E. for potassium content of shoot - 0.04
C.D. for potassium content of root - 0.31
S.E. for potassium content of root - 0.14
C.D. for total potassium uptake - 62
S.E. for total potassium uptake - 28

stage. The potassium content of the root was 2.08, 1.72 and 1.50 per cent at the maximum flowering, mid pod filling and maturity stage respectively. The reduction from the maximum flowering to mid pod filling stage (17 per cent) was found to be highly significant while the reduction of 13 per cent in the content of potassium from the mid pod filling to the maturity stage was not statistically significant.

The content of potassium in the vegetable pods was 1.50 per cent, that in the grain 1.87 per cent and in the pod wall 1.07 per cent.

The total uptake of potassium in the plant showed an increase from the maximum flowering to the mid pod filling stage (316 g to 356 g per plot) which was not statistically significant. On the other hand, the total uptake of potassium at the maturity stage was found to be significantly higher (472 g per plot) than that at the other two stages.

N/K ratio

The N/K ratio presented in Table 4 and Appendix IV. show that the ratio of nitrogen to potassium is maximum at the maximum flowering stage (1.9) which decreases to 1.7 at the mid-pod filling and to 1.4 at the maturity stage of the crop. The reduction in the ratio between different stages is highly significant.

Calcium

The content of calcium in the stems and leaves was

Table 3 d. Calcium content and total uptake at different stages of growth of cowpea.

Mean	Maximum flowering stage			Mid pod filling stage			Maturity stage		
Plant parts	Dry weight kg/plot	Per cent calcium	Calcium uptake g/plot	Dry weight kg/plot	Per cent calcium	Calcium uptake g/plot	Dry weight kg/plot	Per cent calcium	Calcium uptake g/plot
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Stem and leaves	15.3	2.57	388	17.5	2.36	413	23.0	2.45	564
Root	1.1	0.25	3	1.2	0.26	3	1.1	0.34	4
Vegetable pods	-	-	-	2.6	0.07	2	-	-	-
Grain	-	-	-	-	-	-	3.6	0.14	5
Pod wall	-	-	-	-	-	-	0.9	0.42	4
Total	16.4	-	391	21.3	-	418	28.6	-	577

S.E. for calcium content of shoot - 0.22

S.E. for calcium content of root - 0.05

C.D. for total calcium uptake - 93

S.E. for total calcium uptake - 42

highest at the maximum flowering stage and amounted to 2.57 per cent which decreased to 2.36 per cent at the mid pod filling stage. At the maturity stage the content slightly increased and was 2.45 per cent. The difference in the content of calcium between the three stages was not significant though a reduction of about 8 per cent was noticed between the maximum flowering and the mid pod filling stage and 5 per cent between maximum flowering and maturity stage.

Content of calcium in the roots showed a marginal increase from 0.25 to 0.34 per cent as the crop attained maturity. The difference between the different stages was not significant.

Calcium content of the vegetable pods, grain and pod wall was 0.07, 0.14 and 0.42 per cent respectively. Pod wall contained the highest amount of calcium when compared to nitrogen, phosphorus and potassium.

An increasing trend in the total uptake of calcium was noticed from the maximum flowering to the maturity stage. It amounted to the highest value of 577 g per plot at the maturity stage followed by 418 g at the mid pod filling and 391 g at the maximum flowering stage. Significant difference in the total uptake of calcium was noticed between the maturity and the mid pod filling and between maturity and the maximum flowering stages. But there was no significant difference in the total uptake of calcium between the mid pod filling and maximum flowering stage.

N/Ca ratio

The N/Ca ratio presented in the Table 4 and Appendix IV is found to be higher at the maximum flowering and the mid pod filling stage. At the maturity stage it is decreased to 1.20. Though there is apparent difference in the ratio between stages they are not statistically significant.

Magnesium

At the maximum flowering stage the magnesium content of the stem and leaves was 0.40 per cent and it decreased to 0.37 per cent at the mid pod filling and to 0.38 per cent at the maturity stage. The decrease was 8 per cent from the maximum flowering to mid pod filling and 5 per cent from maximum flowering to maturity stage. There was no statistical significance in the reduction of magnesium content in the stems and leaves between the stages.

Not much difference was noticed in the magnesium content of roots between the various stages. The content of magnesium in the roots was 0.25, 0.24 and 0.24 at the maximum flowering, mid pod filling and maturity stage of the crop respectively.

The content of magnesium in the vegetable pods was 0.17 per cent, that of grain 0.24 per cent and of pod wall 0.32 per cent. As in the case of calcium, the pod wall

Table 3 e. Magnesium content and total uptake at different stages of growth of cowpea.

Mean	Maximum flowering stage			Mid pod filling stage			Maturity stage		
Plant parts	Dry weight kg/plot	Per cent magnesium	Magnesium uptake g/plot	Dry weight kg/plot	Per cent magnesium	Magnesium uptake	Dry weight kg/plot	Per cent magnesium	Magnesium uptake g/plot
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Stem and leaves	15.3	0.40	62	17.5	0.37	67.0	23.0	0.38	89
Roots	1.1	0.25	3	1.2	0.24	3.0	1.1	0.24	3
Vegetable pods	-	-	-	2.6	0.17	4.0	-	-	-
Grain	-	-	-	-	-	-	3.6	0.24	8
Vegetable pod wall	-	-	-	-	-	-	0.9	0.32	3
Total	16.4	-	65	21.3	-	74.0	28.6	-	103

S.E. for magnesium content of shoot - 0.01
S.E. for magnesium content of root - 0.02
C.D. for total magnesium uptake - 7
S.E. for total magnesium uptake - 3

recorded maximum value for magnesium.

The total uptake of magnesium in the plant increased from the maximum flowering towards the maturity of the crop. The uptake was found to be highest at the maturity stage (103 g per plot) followed by the mid pod filling stage (74 g per plot) and lowest at the maximum flowering stage (65 g per plot). The difference in the total uptake of magnesium between the maturity and mid pod filling, the maturity and maximum flowering and also between the mid pod filling and maximum flowering stage was found to be highly significant.

N/Mg ratio

The N/Mg ratio presented in Table 4 and Appendix IV show a decreasing trend from the maximum flowering to the maturity stage of the crop. The ratios are 9.1, 8.3 and 6.5 respectively at the maximum flowering, mid pod filling and the maturity stages of the crop. Though there is apparent difference between the maximum flowering and mid pod filling stage they are statistically on par. But the ratio at the maturity stage is found to be inferior to the other two stages.

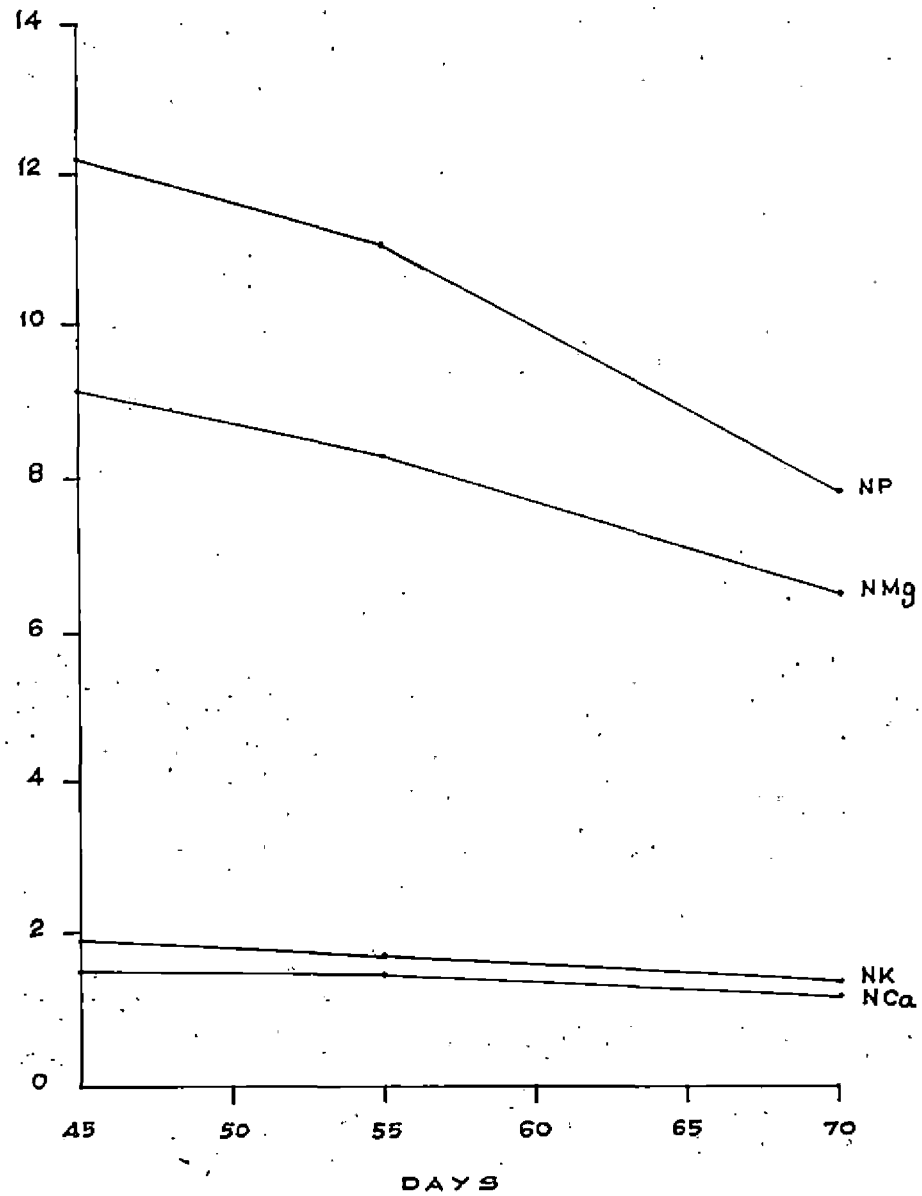
Status of residual nutrients in the soil at the different stages of growth of cowpea

The mean values for the contents of total and available nitrogen, available phosphorus, exchangeable

Table 4. Status of phosphorus, potassium, calcium and magnesium in relation to nitrogen at different stages of growth of cowpea.

Treatment / Mean	N/P ratio	N/K ratio	N/Ca ratio	N/Mg ratio
Maximum flowering stage (T_1)	12.2	1.9	1.5	9.1
Mid pod filling stage (T_2)	11.0	1.7	1.5	8.3
Maturity stage (T_3)	7.8	1.4	1.2	6.5
C.D.	1.3	0.2	-	-
S.E.	0.6	0.1	0.2	0.4

FIG.4. RATIO OF P, K, Ca AND Mg IN RELATION TO NITROGEN AT DIFFERENT STAGES OF GROWTH OF COW PEA.



potassium, calcium and magnesium in the experimental site after the harvest of the cowpea are presented in Table 5 and the analysis of variance in Appendix V.

Total nitrogen

It has been observed that there is significant variation in the content of total nitrogen in the soil at the different stages of growth of cowpea. Nitrogen content in the soil was maximum (0.0558 per cent) when the cowpea was harvested at the maturity stage followed by the mid pod filling (0.0536 per cent) and the maximum flowering stage (0.0514 per cent) compared to the initial status of nitrogen (0.0510 per cent).

Available nitrogen

The available nitrogen status of the soil was found to be not appreciably affected by the different stages of harvest of cowpea. It showed a significant decrease from the initial level of 274 kg to 249 kg per hectare at the maturity stage, 257 kg per hectare at the mid pod filling and 255 kg/ha at the maximum flowering stage.

Available phosphorus

The available phosphorus status of the soil before the starting of the experiment was 37 kg per hectare. The content of available phosphorus in the soil at the different stages of harvest of cowpea showed a general

Table 5. Residual status of total and available nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium in soil at different stages of growth of cowpea.

Treatment / Mean	Total nitrogen Per cent	Available nitrogen kg/ha	Available phosphorus kg/ha	Exchange-able potassium kg/ha	Exchange-able calcium me/100 g soil	Exchange-able magnesium me/100 g soil
1	2	3	4	5	6	7
Maximum flowering stage (T_1)	0.0514	255	28	83	1.14	0.23
Mid pod filling stage (T_2)	0.0536	257	35	68	1.00	0.23
Maturity stage (T_3)	0.0558	249	21	75	0.97	0.21
C.D.	0.0006	-	-	-	-	-
S.E.	0.0003	10	6	11	0.20	0.04

decrease from the initial level. But the changes between the different stages of growth were statistically not significant. The content of available phosphorus was 28, 35 and 21 kg/ha respectively at the maximum flowering, mid pod filling and the maturity stage of the crop. A decrease of 9, 2 and 16 kg P/ha was noticed at the maximum flowering, mid pod filling and maturity stage of the crop compared to the initial status of available phosphorus in the soil.

Exchangeable potassium

The initial content of exchangeable potassium in the soil recorded a value of 105 kg/ha. No significant difference in the potassium content of soil was noted between the stages of harvest of cowpea, although the decrease, when compared to the initial level was significant. A slight decrease in the level of exchangeable potassium was noticed from the maximum flowering (83 kg/ha) to the mid pod filling (68 kg/ha) and an increase from the mid pod filling to 75 kg/ha towards the maturity stage of the crop.

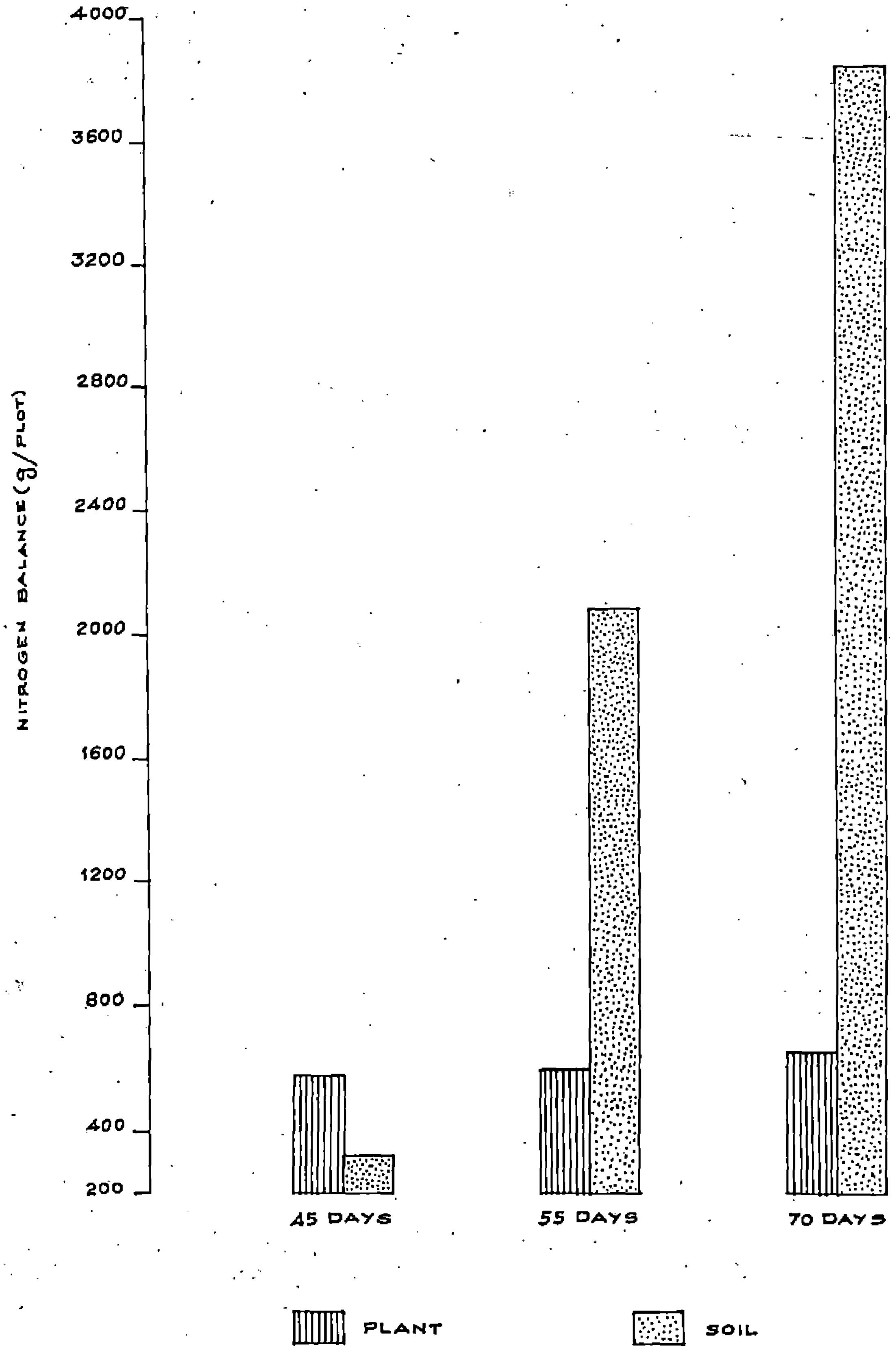
Exchangeable calcium

In the case of exchangeable calcium, the content was not much affected by the stage of harvest of the crop. Though there is a decrease from the initial level of 1.18 me/100 g soil at the different stages, the difference between the stages was not significant. The recorded values were 1.14 me/100 g soil at the maximum flowering, 1.00 me at

Table 6. Total nitrogen balance at different stages of growth of cowpea (g/plot).

Treatment	Soil	Plant	Total
1	2	3	4
Control	40800	-	-
Maximum flowering stage (T_1)	41120	579	41699
Mid pod filling stage (T_2)	42880	599	43479
Maturity stage (T_3)	44640	657	45297

FIG.5. SOIL AND PLANT NITROGEN BALANCE AT DIFFERENT STAGES OF GROWTH OF COWPEA.



the mid pod filling and 0.97 me at the maturity stage.

Exchangeable magnesium

No appreciable difference in the level of exchangeable magnesium in the soil was noted between the three stages of harvest of cowpea. But, when compared to the initial level of 0.30 me/100 g magnesium in the soil, the difference was appreciable. The magnesium content at the maximum flowering, mid pod filling and the maturity stages were only 0.23, 0.23 and 0.21 me/100 g soil respectively.

Residual effect of nitrogen in the soil on a succeeding crop of fodder maize

The residual effect of nitrogen fixed by the cowpea crop harvested at different stages of its growth was studied by raising a bulk crop of fodder maize. The important findings are given below.

Growth and fodder production

The mean values for the height of fodder maize, its fresh weight and total dry matter produced are presented in the Tables 7 a, b, c and the analysis of variance in Appendix VI.

Height of the plant

It may be seen that the height of fodder maize as influenced solely by the residual effect of nitrogen at different stages of growth of cowpea (n_0) was maximum for

Table 7. Residual effect of nitrogen on the growth and fodder production by fodder maize.

a. Height of the plant (cm)

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	81	95	94	99	92
Mid pod filling stage (T_2)	89	87	102	100	95
Maturity stage (T_3)	87	98	105	112	101
Mean	86	93	100	104	

C.D. for T - 7

C.D. for n - 4

C.D. for T x n - 7

the mid pod filling stage (T_2) followed by the maturity (T_3) and the maximum flowering stage (T_1). Similarly the effect due to the residual nitrogen plus nitrogen derived from the incorporated residue (n_1) was highest for T_3 (98 cm) followed by T_1 (95 cm) and T_2 (87 cm). The effect of 30 and 60 kg N/ha over and above the residual nitrogen, in the different plots (n_2 and n_3) was also highest for T_3 (105 and 112 cm respectively). For the four levels of nitrogen n_0, n_1, n_2 and n_3 also, significant differences in the plant height could be noticed. The height of the plant increased from a minimum value of 86 cm in the control plots (n_0) to a maximum value of 104 cm in the treatment n_3.

Fresh weight of fodder

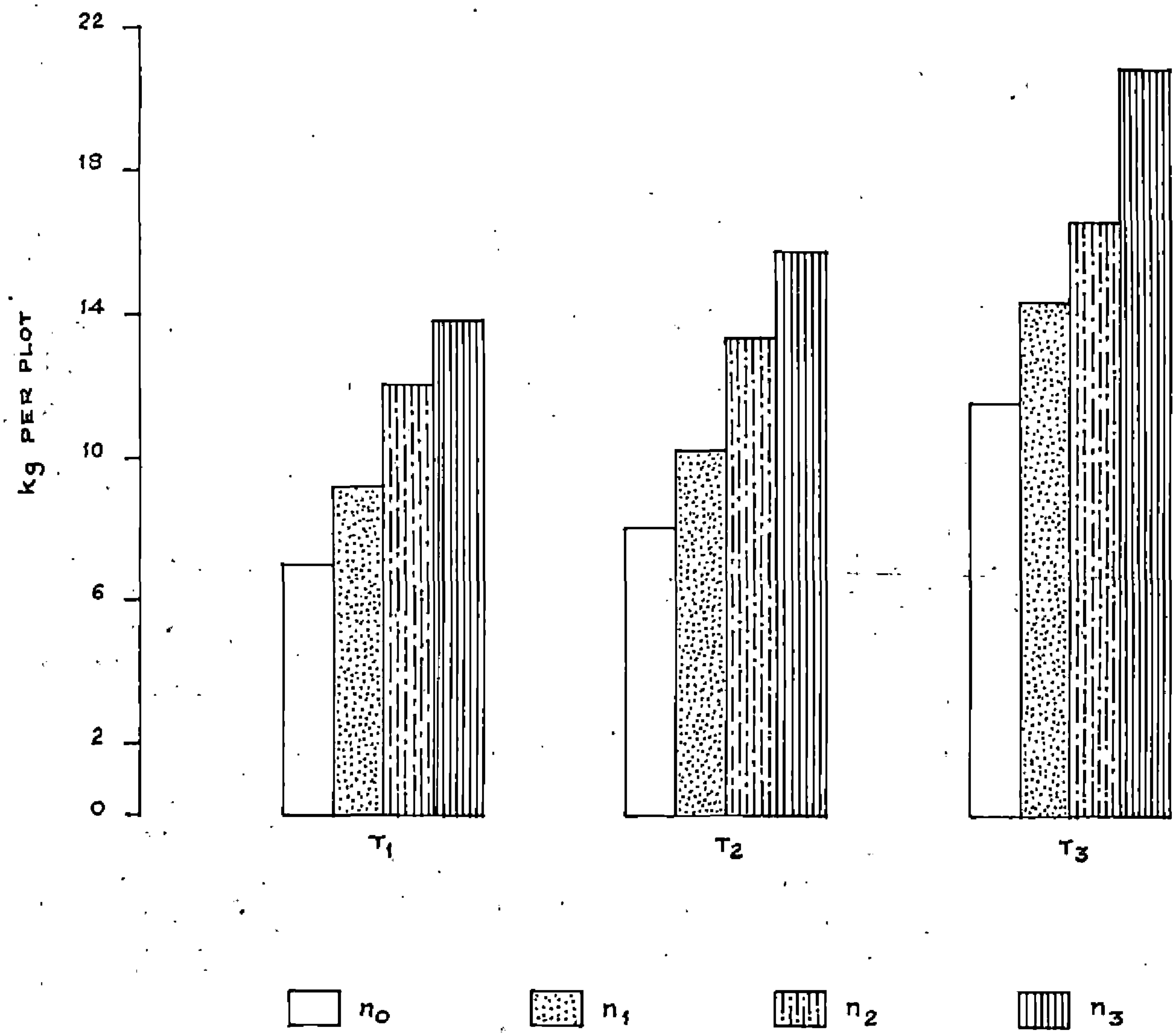
The fresh weight of fodder as influenced by the residual effect of nitrogen in the soil alone at different stages of growth of cowpea increased from 7 kg/plot for the maximum flowering (T_1) stage to 8 and 11.5 kg/plot for the mid pod filling (T_2) and maturity stage (T_3) of the crop. In the same manner the effect due to the residual nitrogen and nitrogen derived from the incorporated residues (n_1) also showed an increasing trend from 9.2 kg/plot for T_1 to 10.2 kg/plot for the mid pod filling stage (T_2) and 14.3 kg/plot for the maturity stage (T_3). A similar pattern was observed for the plants receiving 30 kg (n_2) and 60 kg (n_3) N/ha over and above the residual effect of

Table 7.b. Fresh weight of fodder (kg/plot)

£	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	7.0	9.2	12.0	13.8	10.5
Mid pod filling stage (T_2)	8.0	10.2	13.3	15.7	11.8
Maturity stage (T_3)	11.5	14.3	16.5	20.7	15.7
Mean	8.8	11.2	13.9	16.7	

C.D. for T - 1.3
C.D. for n - 1.1
C.D. for T x n - 1.8

FIG.6. RESIDUAL EFFECT OF NITROGEN ON THE YIELD OF FODDER MAIZE.



the previous crop. In the case of n_2, maximum fresh weight of 16.5 kg/plot was obtained from the plots where the previous crop was harvested at the maturity stage. This was followed by 13.3 kg of fresh fodder for T_2 and 12 kg for T_1. For n_3 also maximum fresh weight (20.7 kg/plot) was obtained from plots receiving the major treatment T_3 followed by 15.7 kg/plot for T_2 and 13.8kg/plot for T_1. Generally the fresh weight of fodder increased with increasing level of nitrogen and it was highly significant. But the interaction between the main plot and subplot (T x N) was not significant.

Dry matter yield

Dry matter yield from the plots solely influenced by the residual effect of nitrogen (n_0) showed an increasing trend from 2.9 kg per plot for the maximum flowering to 3.9 and 4.7 kg per plot for the mid pod filling and maturity stages of the crop. Similarly, the effect due to the residual nitrogen and nitrogen derived from incorporated residue (n_1) was highest (5.2 kg/plot) for the maturity stage followed by 4.2 and 4.0 kg/plot respectively for the mid pod filling and the maximum flowering stages. The effect of 30 kg N/ha over and above the residual nitrogen (n_2) in the different plots was highest for T_3(6.5 kg/plot) followed by T_2 (5.3 kg/plot) and T_1 (4.9 kg/plot). Just like n_2, the effect due to 60 kg N/ha over and above the

Table 7 c. Dry matter yield (kg/plot).

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	2.9	4.0	4.9	6.0	4.4
Mid pod filling stage (T_2)	3.9	4.2	5.3	6.3	4.9
Maturity stage (T_3)	4.7	5.2	6.5	7.9	6.1
Mean	3.8	4.5	5.5	6.7	

C.D. for T - 3.8

C.D. for n - 3.0

C.D. for T x n - 5.1

residual nitrogen in the different plots (n_3), on the dry matter yield increased from 6 kg/plot for T_1 to 6.3 and 7.9 kg/plot for T_2 and T_3 respectively. Here also the dry matter yield increased with increasing levels of nitrogen applied and was highly significant. But the combined effect due to the different stages and levels of nitrogen was not significant.

<u>Nutrient content and total uptake of nutrients</u>

The mean values of the total uptake of nitrogen, phosphorus and potassium in fodder maize are presented in Tables 8 a, b, c and the analysis of variance in Appendix VI.

Nitrogen

Total uptake of nitrogen in fodder maize as influenced only by the residual effect of nitrogen at different stages of growth of cowpea (n_0) was found to be maximum for maturity stage (46 g/plot) followed by the mid pod filling (33 g/plot) and flowering stage (23 g/plot) of the crop respectively. The effect due to residual nitrogen plus nitrogen derived from the incorporated residue on the uptake (n_1) was highest for maturity stage T_3 (62 g/plot) followed by T_2 and T_1 (38 and 37 g/plot respectively). The uptake of nitrogen by fodder maize for 30 kg N/ha applied over and above the residual effect of nitrogen (n_2) increased from 53 g per plot for T_1 to

Table 8. Uptake of nutrients by fodder maize (g/plot).

a. Nitrogen

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	23	37	53	72	46
Mid pod filling stage (T_2)	33	38	60	79	53
Maturity stage (T_3)	46	62	75	116	75
Mean	34	46	63	89	

C.D. for T - 7
C.D. for n - 5
C.D. for T x N - 9

60 and 75 g per plot for T_2 and T_3 respectively. Similarly for 60 kg N/ha applied over and above the residual effect of nitrogen (n_3), highest uptake was noticed for T_3 (116 g per plot) followed by T_2 (79 g/plot) and T_1 (72 g/plot). Thus, uptake of nitrogen increased with increasing levels of nitrogen.

Phosphorus

As in the case of nitrogen, the total uptake of phosphorus also showed a similar pattern. For n_0, the uptake was maximum for T_3 (8 g P/plot) followed by 6 g and 5 g for T_2 and T_1 respectively. The effect due to residual nitrogen and nitrogen derived from the incorporated residue (n_1) on the total uptake was an increase from 6 g per plot at maximum flowering stage to 7 g per plot at maturity stage. Similarly for 30 (n_2) and 60 (n_3) kg N/ha applied over and above the residual nitrogen from the previous crop, the uptake of phosphorus increased from 6 g to 10 g/plot and 9 g to 12 g per plot respectively from the maximum flowering to the maturity stage of the crop. Uptake of phosphorus was found to be highly significant for level of nitrogen.

Potassium

Total uptake of potassium was also found to increase with increasing levels of nitrogen. Uptake of potassium as influenced only by the residual effect of nitrogen at

b. Phosphorus

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	5	6	6	9	7
Mid pod filling stage (T_2)	6	6	8	9	7
Maturity stage (T_3)	8	7	10	12	9
Mean	6	6	8	10	

C.D. for T - 2

C.D. for n - 1

C.D. for T x n - 2

c. Potassium

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	40	52	67	75	59
Mid pod filling stage (T_2)	58	56	82	86	71
Maturity stage (T_3)	66	73	84	87	78
Mean	55	60	78	83	

C.D. for T - 11

C.D. for n - 7

C.D. for T x n - 11

different stages of growth of cowpea (n_0) increased from 40 g per plot for maximum flowering to 58 and 66 g per plot for the mid pod filling and the maturity stages of the crop. In the same manner, the effect due to the residual nitrogen plus nitrogen derived from incorporated residues (n_1) also showed an increasing trend from 52 g for T_1, 56 g for T_2 and 73 g per plot for T_3. For 30 (n_2) and 60 (n_3) kg N/ha applied over and above the residual nitrogen, the same pattern was followed. The uptake for n_2 increased from 67 g for T_1, 82 g for T_2 and 84 g for T_3. For n_3 also the uptake showed an increasing trend from 75 g for T_1 to 86 g and 87.6 g per plot for T_2 and T_3 respectively. Among the different levels of nitrogen tried, the total uptake of potassium showed significant effect. There was no interaction effect between the stage of the crop and different levels of nitrogen.

<u>Residual status of nutrients after the harvest of fodder maize</u>

The mean values of total nitrogen, available nitrogen and phosphorus as well as exchangeable potassium status of the soil after the harvest of the fodder maize are presented in Tables 9 a, b, c and the analysis of variance in Appendix VII.

Total nitrogen

It may be seen that the content of total residual

Table 9. Residual status of total nitrogen, available nitrogen, phosphorus, exchangeable potassium after the cultivation of fodder maize.

a. Total nitrogen (per cent)

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	0.0509	0.0509	0.0510	0.0510	0.0510
Mid pod filling stage (T_2)	0.0530	0.0527	0.0528	0.0528	0.0528
Maturity stage (T_3)	0.0549	0.0549	0.0548	0.0548	0.0549
Mean	0.0529	0.0528	0.0529	0.0529	

C.D. for T - 0.0001

C.D. for n - 0.0002

C.D. for T x n - 0.0003

nitrogen in the soil after the harvest of the fodder maize was highest for maturity stage (T_3) which recorded a value of 0.0549 per cent nitrogen. The soils at the mid pod filling and maximum flowering stage (T_2 and T_1) recorded 0.0530 and 0.0509 per cent nitrogen respectively. The effect due to residual nitrogen plus nitrogen derived from incorporated residue (n_1) was maximum for maturity stage (0.0549) which was followed by the mid pod filling (0.0527 per cent) and maximum flowering stages (0.0509 per cent). The effect of 30 kg N/ha (n_2) over and above the residual nitrogen was maximum for the maturity stage (0.0548) followed by 0.0528 per cent for the mid pod filling and 0.0510 for the maximum flowering stage. Similarly, the effect of 60 kg N/ha (n_3) over and above the residual nitrogen in the different plots was highest for the maturity stage (0.0548 per cent) followed by mid pod filling and maximum flowering stages (0.0528 and 0.0510 per cent respectively). Among the different levels of nitrogen tested no significant difference was noticed.

The difference in the level of total nitrogen per cent was 0.0005 for the maximum flowering, 0.0006 for the mid pod filling and 0.0009 for the maturity stage compared to the original level for plots receiving treatment n_0. For plots receiving the treatment n_1 (residual nitrogen plus nitrogen derived from incorporated residues) the difference from the original level of nitrogen per cent was 0.0006 for maximum flowering and 0.001 for the mid pod filling and maturity stages. In the case of plots receiving 30 kg N/ha over and above the residual nitrogen, a difference of 0.0006 was noticed for maximum flowering, 0.001 for the mid pod filling and 0.0012 for the maturity stage of the crop. For the plots receiving 60 kg N/ha over and above the residual nitrogen, a reduction of 0.0008 per cent was noticed for the maximum flowering 0.001 per cent for the mid pod filling and 0.0014 per cent for the maturity stage of the crop. Maximum difference was noticed for the treatment T_3n_3 from where the fresh weight of the crop was highest.

Available nitrogen

The residual status of available nitrogen in the soil as influenced only by the different stages of growth of cowpea (n_0) was maximum in plots where the cowpea was harvested, the maximum flowering stage - T_1 (240 kg/ha) followed by mid pod filling (234 kg/ha) and maturity stage (215 kg/ha) The level of nitrogen for the plots receiving the residual nitrogen from cowpea plus nitrogen derived from incorporated residues (n_1) was highest for the maximum flowering stage (247 kg/ha) followed by the mid pod filling and maturity stages (240 and 228 kg/ha respectively). The level of nitrogen in the plots receiving

Table 9 b. Available nitrogen (kg/ha)

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	240	247	228	215	233
Mid pod filling stage (T_2)	234	240	225	225	231
Maturity stage (T_3)	215	228	234	234	228
Mean	230	238	229	225	

S.E. for T - 5

S.E. for n - 6

S.E. for T x n - 11

30 kg N/ha over and above the residual nitrogen of cowpea (n_2) was highest for the maturity stage (234 kg/ha). The residual status of available nitrogen was 228 and 225 kg/ha respectively for the maximum flowering and mid pod filling stage. For plots receiving 60 kg N/ha over and above the residual nitrogen from cowpea (n_3), the value was highest for the maturity stage (234 kg/ha), followed by the mid pod filling and maximum flowering stage (225 and 215 kg/ha respectively). Though there is apparent differenoo in the available nitrogen status between different levels of nitrogen they are statistically on par and not significant.

The content of available nitrogen after the harvest of the fodder maize was lower than the initial level. For the treatment n_0, maximum reduction was noticed for plots receiving the treatment T_2 (mid pod filling stage). For the treatment n_1, a difference of 21 kg/ha was noticed for the plots receiving the treatment T_3 (maturity stage) and 19 kg/ha each for T_1 (maximum flowering) and T_2 (mid pod filling stage) from the original level. For the treatment n_2 maximum reduction of 32 kg/ha was noticed for plots receiving T_1 followed by maturity (17 kg/ha) and mid pod filling stages (13 kg/ha). For the treatment n_3, a reduction of 23, 9, 31 kg/ha was observed for the plots receiving the treatments T_1, T_2 and T_3 respectively.

Available phosphorus

Available phosphorus content of the soil solely influenced by the different stages of cowpea was maximum for the maximum flowering (37 kg/ha) followed by maturity (31 kg/ha) and the mid pod filling stage (29 kg/ha). For plots receiving the treatment n_1, the content of phosphorus was 29, 32 and 31 kg/ha for the maximum flowering, mid pod filling and the maturity stage of the crop. For treatment n_2, the content was 25 kg/ha for the maximum flowering, 33 kg/ha for the mid pod filling and 39 kg/ha for the maturity stage of the crop. The phosphorus content of the soil in plots receiving the treatment n_3 was 28, 46 and 37 kg/ha respectively for the maximum flowering, mid pod filling and maturity stage of the crop. The difference in the content of phosphorus was statistically not significant and they are on par.

Exchangeable potassium

It has been observed that the content of potassium in the soil solely influenced by different stages of growth of cowpea was maximum for the maturity stage (89 kg/ha) followed by maximum flowering stage (78 kg/ha) and mid pod filling stage (69 kg/ha). For plots receiving the treatment n_1, the highest value was recorded for mid pod filling stage (86 kg/ha) and 83 and 75 kg/ha for maturity stage and maximum flowering stage. The content of potassium in the

Table 9 c. Available phosphorus (kg/ha)

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	37	29	25	28	30
Mid pod filling stage (T_2)	29	32	33	46	35
Maturity stage (T_3)	31	31	39	37	35
Mean	32	31	32	37	

S.E. for T - 4

S.E. for n - 4

S.E. for T x n - 6

Table 9 d. Exchangeable potassium (kg/ha)

	n_0	n_1	n_2	n_3	Mean
1	2	3	4	5	6
Maximum flowering stage (T_1)	78	75	86	84	81
Mid pod filling stage (T_2)	69	86	78	69	76
Maturity stage (T_3)	89	83	87	77	84
Mean	79	81	84	77	

S.E. for T - 5

S.E. for n - 5

S.E. for T x n 8

case of plots receiving the treatment n_2 was 86, 78 and 87 kg/ha respectively for the maximum flowering, mid pod filling and maturity stage of the crop. In the case of plots receiving the treatment n_3 highest value of 84 kg/ha was recorded for the maximum flowering stage followed by maturity and mid pod filling stage (77 and 69 kg/ha respectively). However, the content of potassium was statistically on par in the different treatments.

DISCUSSION

DISCUSSION

High nitrogen fixation capacity by a legume is the most desirable plant characteristic to be exploited since the legumes are known to largely differ in this respect even under almost uniform soil and climatic conditions. Therefore, it is imperative that we understand the development of the nitrogen fixing system, the uptake of nitrogen and fixation at different stages of growth of the legume particularly under tropical situations. Legumes are used either as green manure at the maximum flowering stage, vegetable when the crop is harvested at the end of the vegetative phase or as grain where the plant is permitted to attain maturity. The magnitude of enrichment of soil nitrogen at each stage is also directed by utilization of the stems and leaves which contain more than 80 per cent of the nitrogen accumulated by the plant. The quantification of nitrogen gained by way of fixation at each of these stages is thus necessary to evaluate and reorganise the utilization pattern of a particular legume.

The results of the experiment to study nitrogen fixation by cowpea as influenced by the stage of growth and duration of the crop and its residual effect on a succeeding crop of fodder maize are discussed here.

An increase in soil nitrogen and a simultaneous increase in the nitrogen content of the standing crop or in the nitrogen removed in crops can be measured and taken as an index of the 'amount of nitrogen fixed' by a legume - Rhizobium symbiotic association (Greenland, 1975). This can be computed by careful determination of the various components which ultimately decide the balance of nitrogen in a given soil-plant system.

From the results presented on the growth and nodulation pattern of cowpea as well as the nitrogen content of the soil-plant system at the three stages of harvest, a critical evaluation of the amount of nitrogen fixed by the crop can be made.

Growth and nodulation of cowpea

The results presented in Table 2 show that there is an increase in the total dry matter yield of cowpea with an increase in its duration of growth. Eventhough the total dry matter content showed an increase with the age of the plant, the per cent nitrogen in the vegetative plant parts such as stems, leaves and roots showed a gradual decrease. The highest nitrogen content was noticed for the plant parts at the maximum flowering stage followed by the mid pod filling and maturity stages. Specific data on the distribution of nitrogen in various plant parts is not available in reported literature. However, a decrease in nitrogen content with aging of leguminous plants has been reported (Fred et al.; 1932, Whiteman, 1971; Mura and Burhan, 1974).

The decline in the nitrogen content of the plant is seen to run parallel with a decrease in the number and fresh weight of nodules at the corresponding stages. Any legume plant at its maximum flowering stage is considered to be at its peak efficiency period of nitrogen assimilation as seen from ample evidences cited in literature ([illegible], 1937; Nutman, 1971; Anonymous, 1973; Summerfield, 1977). These observations have led to the practice of ploughing-in of leguminous plants as a green manure at their maximum flowering stage, for enrichment of the soil nitrogen as well as for improving the physico-chemical and biological properties of soil.

The diminution in the number of root nodules after the maximum flowering stage of the crop has been considered by many as one of the reasons for the decline in the nitrogen content of the plants after this stage. The dwindling nitrogen fixation activity in several of the legumes has been associated with a decrease in the nodule number, as well as a decrease in the nitrogen content of plant parts (Sinha, 1976).

It is often felt that the full nitrogen fixing capacity of the legume is reached by its maximum flowering stage and lack of appreciable nitrogen fixation after this stage has been considered to be associated with a decrease in the number of root nodules (Zablotowicz, 1981). The correlation coefficient values (r=0.548, 0.369, 0.158) between the nitrogen content of plant parts and the number of nodules at the three stages of growth of cowpea did not however reveal any significant relationship to support this view. But, a significant positive relationship is noticed between the mean values of the nodule number and nitrogen content for the three different stages (r=0.842) when considered together.

A decline in the number and fresh weight of nodules with increasing age of the crop might be due to the sloughing-off of the senile nodules which is not counterbalanced by fresh nodulation (Buckman and Brady, 1960; Alexander, 1978).

Nitrogen gains by cowpea at different stages

Eventhough the percentage of nitrogen in the various plant parts showed a decrease with increasing age of the crop, the pattern of total uptake of nitrogen revealed a significant increase from the maximum flowering stage to the maturity stage of the crop. On a whole plant basis, the total nitrogen uptake was highest (657 g per plot) at the maturity stage. While the uptake of nitrogen at maximum flowering stage (579 g); eventhough significantly lower than the uptake of nitrogen at the maturity stage, accounted for nearly 88 per cent of the total nitrogen gained by the plant.

It may be seen from the results presented in Table 3 a that the decrease in the percentage of nitrogen in the plant parts with advancing growth has been compensated for by a gain in the total dry matter content which has helped to maintain a higher rate of nitrogen uptake by the plant. The decrease in the nitrogen content of stem, leaves and roots might be due to the translocation of nitrogen to the developing pods and grain as has been pointed out by several workers (Ohlrogge, 1960; Hanway and Weber, 1971 a, and Pal and Saxena, 1976). The nitrogen accumulated in the tender pods (harvested for vegetable purpose) and mature grain was only 6 and 22 per cent respectively of the total uptake indicating that translocation alone cannot be the only reason for a lowering of the nitrogen content in the vegetative parts. In view of the higher dry matter produced after the maximum flowering stage, it might be reasonable to attribute this lowering in nitrogen content to a dilution effect on the nitrogen previously assimilated by the plant.

The results also bring to light the significance of the stage of harvest in deciding the quality of non-edible portions of a legume to be used as a green manure. The variation in the nitrogen content of the roots is more critical than that of the stem and leaves. While the nitrogen content of the stem and leaves ranged between 3.67 and 2.19 per cent, the values for the roots were 1.90, 1.33 and 1.19 per cent at the maximum flowering, mid pod filling and maturity stages respectively.

It is a common practice among farmers to harvest away the tops and leave the roots alone in the soil for decomposition. The proportion of nitrogen released during the decomposition of the residues is governed by the chemical composition of these residues, especially the nitrogen content. A nitrogen content of 1.33 per cent has been fixed (Alexander, 1978) as critical for preventing the net immobilisation of nitrogen during organic matter decomposition. The nitrogen content in the roots of cowpea at maturity stage is only 1.19 per cent, which is much below this critical level. During the decomposition of such nitrogen poor root residues having a wide C:N ratio, the entire nitrogen may not get mineralised in a short time and may create temporary immobilization of nitrogen in the soil which can become a serious problem for the succeeding crops. Similar instances of nitrogen immobilization due to incorporation of legume roots have been reported by Ganry et al. (1978). Appropriate soil management measures are needed for the gradual release of the immobilized nitrogen.

Uptake of other nutrients

Unlike the nitrogen content, the phosphorus content of the plant parts did not show any significant variation at different stages, eventhough its total uptake was maximum at the maturity stage. This shows that unlike nitrogen which suffered a significant dilution effect in the plant, the phosphorus content was maintained by the continued phosphorus absorption even after the maximum flowering stage which led to a higher net accumulation of phosphorus in the plant.

However, it may be noted that the N/P ratios registered a decrease from 12.2 to 11.2 at the maximum flowering stage to the mid pod filling stage and from 11.2 to 7.8 from the midpod filling to the maturity stage. This decrease in the ratio inspite of an increase in the uptake of both nitrogen and phosphorus, might be caused either due to a proportionately lower uptake of nitrogen than phosphorus or to an increased utilisation of phosphorus in relation to nitrogen from the maximum flowering stage onwards. Singh and Jain (1968) and Latha (1984) have reported a decrease in the percentage of phosphorus with age in cowpea. The results from the present study also indicate a decreasing trend in phosphorus content with age which was not significant. However, the total uptake of phosphorus continued to increase with the age of the plant.

The content and uptake of potassium, calcium and magnesium in cowpea at different stages of harvest also followed the same trend as in the case of phosphorus. The ratios of these elements with respect to nitrogen revealed a decreasing trend probably signifying a higher uptake of these nutrients with advancing age of cowpea. Ustimento and Popov (1978) have reported such a gradual decrease in the NPK contents of the plant parts during the growth and development of the plant, maximum uptake of nutrients being observed during intensive pod formation. The total uptake of all plant nutrients by cowpea also increased with age, eventhough in terms of percentage, the values showed a decreasing trend.

Soil nitrogen status at different stages of growth of cowpea

From the results presented in Table 5, a gradual increase in the content of total nitrogen of soil is evident with increase in duration of the crop. Since the total nitrogen content of the soil is found to increase at and beyond the maximum flowering stage without a correspondingly very high increase in the plant nitrogen, it might be presumed that most of the nitrogen fixed by the legume - *Rhizobium* symbiosis after the maximum flowering stage has been excreted into the soil. The nitrogen already assimilated by the plant along with a comparatively smaller fraction absorbed from the soil might have been sufficient to meet the nitrogen demands of the plant beyond the maximum flowering stage.

The available nitrogen content of the soil, eventhough it registered a remarkable decrease from the initial level, was not appreciably different at the three stages of growth of cowpea. This might be due to a comparatively lower uptake of soil nitrogen by the plant after it has passed the maximum flowering stage.

Inspite of the increase in the total nitrogen content in the soil at the three stages, the level of available nitrogen did not show any increase as could be naturally expected. A slow mineralisation of the fixed nitrogen on account of its stabilisation by reactions with aromatic poly phenols of microbial or plant origin (Bartholomew, 1965) or with montmorillonite type of clay minerals present in the soil (Sorensen, 1975) might be a probable factor which has prevented a net increase in the status of available nitrogen.

The continued increase in the total nitrogen content of soil is not on par with the prevalent view that after maximum flowering stage, the nodule number decreases and the plant loses its capacity for nitrogen fixation (Anonymous, 1972; Anonymous, 1974; Sinha, 1976). The evidence from the present study clearly indicates that nitrogen fixation rate actually gains intensity from the maximum flowering stage onwards and reaches a peak value at the grain or maturity stage. The total nitrogen gained by the plant at the maturity stage is significantly greater than that at the other two stages where comparatively smaller amounts of nitrogen are excreted into the soil. The greater enrichment of soil nitrogen after the maximum flowering stage clearly shows that the nitrogen which is continuously fixed by the plant and which is probably in excess of the plant's demand is being excreted into the soil. Lack of carbohydrate supply resulting from a waning of the photosynthetic activity of the plant due to the onset of senescence in the leaves after the maximum flowering stage may prevent the nitrogen fixed by the Rhizobia from being fixed by the plant as proteins (Dart, 1975; Alexander, 1978). It has also been pointed out that nitrogen fixation activity can continue in the resting bacteriods during the static phase in the life cycle of Rhizobia (Dart, 1975). It is possible that the bacteriods that are still present in the nodules even after the observed decline in the number of nodules may be responsible for this function.

The net nitrogen gain in the soil-plant system, considered as a continuous unit is highest at the maturity stage which is successively followed by the other two stages. The increase in total nitrogen balance at maturity phase suggests the possibility that nitrogen fixing mechanisms still continue to operate beyond the maximum flowering and pod filling stages. As the plant is unable to utilise the entire amount of nitrogen fixed, the unutilised nitrogen in all probability is being excreted into the soil, enriching the same. Since the nitrogen excreted by the legume is utilised by the different plants under mixed culture, there is every likelihood of the residual effect in the soil to be much less (Henzell and Vallis, 1975; Whitney, 1975).

The total nitrogen gain by way of fixation by cowpea, computed from the total plant uptake and increase in the total nitrogen content of the soil comes to 23, 67 and 112 kg per hectare at the maximum flowering, mid pod filling and maturity stages of growth respectively. These values are much above the range of 30 to 60 kg N/ha estimated under average Indian conditions (Mehta, 1970).

Residual status of other nutrients in the soil after the cowpea crop

The status of available phosphorus aswell as that of exchangeable potassium, calcium and magnesium in the soils which showed a steady decrease with increasing duration of the crop, suggests a natural depletion due to the increasing plant uptake. The slight increase in the available phosphorus status of the soil at the mid pod filling stage, even though not significantly higher than that at the other two stages, might be due to more of the insoluble soil phosphorus getting transformed into available forms. Such increase in available phosphorus can occur due to the greater solubilisation of phosphorus resulting from a favourable activity of the rhizosphere microflora (Alexander, 1978).

Residual effect of nitrogen in the soil on a succeeding crop of fodder maize.

The general growth and yield pattern as well as nitrogen uptake of fodder maize showed an increasing trend in the plots where cowpea was grown for a longer duration. Thus, maximum dry matter from fodder maize was obtained from the plots where cowpea was grown upto maturity. The results are in confirmation of the finding that the maximum gain in soil nitrogen is achieved when the cowpea is permitted to grow upto maturity.

At any of the stages, the effect of residual nitrogen and the combined effect of the residual nitrogen plus the incorporated haulm was not on par with the added effect of 30 kg N/ha over and above the residual soil nitrogen. This indicates that the nitrogen made available from the decomposition of plant residues was not equivalent even to that of 30 kg N/ha. At the same time, effect of residual nitrogen alone at the maturity stage of cowpea is almost on par with the effect of 30 kg N plus the residual effect of nitrogen at the maximum flowering stage. The increase in the yield of fodder maize due to the incorporated haulm is almost equal at the three stages, while the effect due to the residual nitrogen in the soil is much higher at the maturity stage compared to the other two stages.

The results thus indicate that eventhough cowpea can be utilised as a vegetable and also as grain, the more important function of nitrogen enrichment of soils is attained only when it is utilised as grain. The continued increase in the nitrogen content of soil demonstrate a viable microbial association in cowpea which is able to fix nitrogen even beyond the maximum flowering stage. Such legumes which retain a high degree of nodule viability between flowering and grain filling stages and which are able to contribute to soil nitrogen and benefit the crop grown in the following season will definitely prove best in the nitrogen economy of our soils.

Very few experimenters have examined the residual benefit for subsequent crops of the nitrogen fixed by a legume crop. The highest fodder yield of 20.7 t/ha was obtained from the plots which received an additional amount of 60 kg nitrogen per hectare over the residual nitrogen in plots where cowpea was grown to maturity. This yield is on par with the reported yield of 20.2 t/ha for fodder maize in Vellayani (Mercy George, 1981) obtained by the application of 120 kg N/ha. Based on these findings the residual effect of nitrogen by cowpea grown to maturity may be reckoned as equivalent to a minimum of 60 kg of nitrogen per hectare. This finding is in agreement with the reports of Giri and De (1979) and Kumar Rao and Dart (1980) who reported a residual effect of 60 kg nitrogen from groundnut and 40 kg nitrogen from pigeon pea respectively.

SUMMARY

SUMMARY

A field study was carried out to quantify the total nitrogen gain at various stages of growth of cowpea with a view of finding out how best we can utilise the legume Rhizobium symbiosis to trap the nitrogen reserve of the atmosphere. The residual effect of the fixed nitrogen in the soil was studied by growing a succeeding crop of fodder maize. The important findings of the study are summarised below.

1. The growth characters and dry matter production of cowpea increased with increasing age of the crop. However, the number and weight of the root nodules decreased with advancing age. Maximum nodulation was observed at the maximum flowering stage, which declined from the midpod filling to the maturity stage.

2. The content of plant nitrogen decreased with advancing age of the crop eventhough the total uptake of nitrogen showed an increasing trend from the maximum flowering to maturity stage. The nitrogen uptake increased from 579 g/plot to a significantly higher level of 657 g/plot at the time of harvest.

3. By the maximum flowering stage, nearly 88 per cent of the total nitrogen assimilated by the plant was accumulated in the tops At this stage 96 per cent of the

total nitrogen assimilated by the whole plant was distributed in the tops and rest in the roots.

4. The uptake of other nutrients like phosphorus, potassium, calcium and magnesium showed an increasing trend with duration of the crop and recorded maximum value at maturity stage of the crop. The comparative status of phosphorus, potassium, calcium and magnesium assimilated by the plant with respect to nitrogen also revealed an increasing trend with the advance in growth of the crop. The ratios of N/P, N/K, N/Ca and N/Mg were narrowed with age indicating a higher uptake of these nutrients with respect to nitrogen towards the later stages of growth of the crop.

5. A gradual increase in the content of total residual nitrogen of the soil was noted with increase in duration of the crop. The content was maximum and significantly higher than the initial level at the maturity stage (0.0558 per cent) followed by the mid pod filling (0.0536 per cent) and the maximum flowering stage (0.0514 per cent). This indicates that the nitrogen fixing processes in cowpea are active during its entire period of growth gaining pace after the maximum flowering stage. It also makes clear that an actual gain in soil nitrogen is obtained only after the maximum flowering stage when most of the nitrogen fixed by the legume - Rhizobium symbiosis is excreted into the soil.

6. The available nitrogen status of the soil at the

various stages of growth of cowpea remained rather unaltered, eventhough it decreased appreciably from the initial status.

7. Net positive gain in total nitrogen in the soil-plant system was of the order of 899, 2679 and 4479 g per plot equivalent to 23, 67 and 112 kg/ha being recorded at the maximum flowering, mid pod filling and maturity stages of the crop respectively,

8. The finding that the net nitrogen in the soil plant system, considered as a single unit continued to increase and was higher at the maturity stage followed by the other two stages suggests that nitrogen fixing mechanism still continue to operate beyond the maximum flowering and mid pod filling stage.

9. The highest residual effect of the nitrogen fixed by the cowpea on a succeeding crop of fodder maize was noticed in plots where it was grown upto maturity. This was revealed by the highest content of dry matter and total yield of fodder. The general growth characters as well as nitrogen uptake by fodder maize showed an increasing trend in the plots where cowpea was grown for a longer duration.

10. At any of the stages, the effect of the residual nitrogen plus the nitrogen derived from the incorporated haulm was not on par with the effect of 30 kg N/ha added over and above the residual soil nitrogen in increasing the fodder yield or its nitrogen uptake. This shows that the

nitrogen made available from the decomposition of plant residues at any of the stages may not be considered as equivalent to that of 30 kg N/ha.

11. The effect due to residual nitrogen in the soil was highest at the maturity stage compared to the other two stages, as was evident from the higher fodder yield and nitrogen uptake in these treatments.

12. The highest fodder yield of 20.7 t/ha obtained from plots which received an additional amount of 60 kg N per hectare over the residual nitrogen in plots where cowpea was grown to maturity was found to be equivalent to the yield of fodder maize obtained by the application of 120 kg N per hectare. The residual effect of nitrogen in the soil imparted by cowpea grown to maturity may thus be reckoned as equivalent to the benefits obtained by the application of a minimum amount of 60 kg N/ha.

13. The uptake of nutrients such as nitrogen, phosphorus and potassium by fodder maize was also highest in the plots where cowpea was grown upto maturity.

The results of the present study thus emphasise the fact that cowpea is continuing the process of nitrogen fixation beyond its maximum flowering stage. The nitrogen fixation rate actually gains intensity from the maximum flowering stage onwards and reaches a peak value at the grain or the maturity stage. It is also suggestive that maximum nitrogen gain through fixation by growing legume crops in general can be achieved only if the plant is allowed to complete its full growth period. Use of grain legumes for _in situ_ green manuring or as vegetable may in effect be curtailing the plant's ability to continue fixation of atmospheric nitrogen. Eventhough cowpea and other legumes are consumed as a vegetable, the more important function of nitrogen enrichment of soils can be attained only if the plant is permitted to grow upto maturity. In fact, the status of nitrogen in the grain is much higher than that in the vegetables.

Incorporation of such legumes which continue nitrogen fixation even upto the grain stage into our farming system may go a great way in improving the nitrogen status of soils by natural processes of biological nitrogen fixation.

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*Originals not seen

APPENDICES

APPENDIX I

Abstract of the analyses of variance for the height of the plant, number of nodules per plant, weight of nodules per plant, fresh weight of harvested portion and dry matter yield per plot at different stages of growth of cowpea.

Source	df	Mean squares				
		Height of the plant	Number of nodules per plant	Weight of nodules per plant	Fresh weight of harvested portion	Dry matter yield per plot
Block	5	98.1183*	17.2889**	0.0195*	59.8168**	25.9473**
Treatment	2	146.8499*	150.8889**	0.0566**	336.5051**	227.8847**
Error	10	26.8538	1.8222	0.0049	2.5205	0.4776

*Significant at 0.05 level

**Significant at 0.01 level

APPENDIX II

Abstract of analyses of variance for the nitrogen content of shoot, root, uptake of nitrogen, phosphorus content of shoot, root, uptake of phosphorus at different stages of growth of cowpea.

Source	df	Mean squares					
		Nitrogen content of shoot	Nitrogen content of root	Uptake of nitrogen	Phosphorus content of shoot	Phosphorus content of root	Uptake of phosphorus
Block	5	0.0762	0.0543	13982.9034**	0.0094**	0.0037	726.1368**
Treatment	2	3.3580**	0.8557**	9808.0371**	0.0024	0.0008	2545.7712**
Error	10	0.0245	0.0462	619.6167	0.00093	0.0018	53.4406

*Significant at 0.05 level

**Significant at 0.01 level

APPENDIX III

Abstract of the analyses of variance for the potassium content of shoot, root, uptake of potassium, calcium content of shoot, root, uptake of calcium at different stages of growth of cowpea.

Source	df	Mean squares					
		Potassium content of	Potassium content	Uptake of potassium	Calcium content of shoot	Calcium content of root	Uptake of calcium
Block	5	0.0463	0.0133	10784.8825**	0.0955	0.00804	9124.6545
Treatment	2	0.1050	0.5217**	39025.4640**	0.0653	0.0174	60235.9863**
Error	10	0.0060	0.0570	2322.9387	0.1451	0.0086	5201.7672

*Significant at 0.05 level

**Significant at 0.01 level

APPENDIX IV

Abstract of the analyses of variance for the magnesium content of shoot, root, uptake of magnesium, status of phosphorus, potassium, calcium and magnesium in relation to nitrogen at different stages of growth of cowpea.

Source	df	Mean squares						
		Magnesium content of shoot	Magnesium content of root	Uptake of magnesium	N/P ratio	N/K ratio	N/Ca ratio	N/Mg ratio
Block	5	0.0019*	0.00052	720.6217**	12.9296**	0.0593*	0.0687	2.3442**
Treatment	2	0.0011	0.0002	2396.6842**	31.3636**	0.2972**	0.2292**	10.1167**
Error	10	0.0004	0.0010	30.7610	0.9761	0.0166	0.0753	0.3786

*Significant at 0.05 level

**Significant at 0.01 level

APPENDIX V

Abstract of the analyses of variance for the residual status of total and available nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium in soil at different stages of growth of cowpea.

Source	df	Mean squares					
		Total nitrogen	Available nitrogen	Available phosphorus	Exchange-able potassium	Exchange-able calcium	Exchange-able magnesium
Block	5	0.00000002	846.7479	18.8887	143.8379	0.1561	0.0018
Treatment	2	0.0000291**	119.0286	300.1681	334.5067	0.0498	0.0009
Error	10	0.00000018	290.9650	93.1637	375.9855	0.1148	0.0038

**Significant at 0.01 level

APPENDIX VI

Abstract of the analyses of variance for the height of the plant, fresh weight and dry matter yield per plot, uptake of nitrogen, phosphorus and potassium by fodder maize at the time of harvest.

Source	df	Mean squares					
		Height of the plant	Fresh weight	Dry matter yield	Uptake of nitrogen	Uptake of phosphorus	Uptake of potassium
Block	5	111.5988	15.6139*	0.7051	181.4348	18.6354	511.5005
Main plot	2	428.4696	179.5972**	17.4359**	5301.9206**	32.5138	2233.4354**
Error (a)	10	116.2029	4.1639	0.3487	113.0880	8.6767	271.3979
Sub plot	3	1155.1189**	209.1620**	29.1331**	10396.5457**	51.1104**	3314.3341
Main plot x Sub plot	6	118.8620*	2.0231	0.3157	243.2574**	4.4589	119.4246
Error (b)	45	41.2914	2.4604	0.1936	55.2793	3.8623	95.7741

*Significant at 0.05 level

**Significant at 0.01 level

APPENDIX VII

Abstract of the analyses of variance for the residual status of total and available nitrogen, available phosphorus and exchangeable potassium in soil after the cultivation of fodder maize.

Source	df	Mean squares			
		Total nitrogen	Available nitrogen	Available phosphorus	Exchangeable potassium
Block	5	0.00000016*	723.3707	155.3278	1439.6006*
Main plot	2	0.000051**	148.6264	202.9908	416.0967
Error (a)	10	0.000000035	294.7422	165.5529	293.1646
Sub plot	3	0.000000025	570.4268	128.0821	169.1371
Main plot x Sub plot	6	0.000000043	709.0580	238.5743	277.9754
Error (b)	45	0.000000021	343.5477	124.2189	212.6523

*Significant at 0.05 level

**Significant at 0.01 level

NITROGEN FIXATION BY COWPEA AS INFLUENCED BY THE STAGE OF GROWTH AND DURATION OF CROP

By

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ABSTRACT OF A THESIS
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ABSTRACT

A field experiment was conducted in the College of Agriculture, Vellayani to study the quantity of nitrogen fixed by cowpea at various stages of growth and also to find its residual effect on a succeeding crop of fodder maize. The field trial was laid out as RBD and split plot design with six replications.

The study revealed that the growth characters and dry matter production of cowpea increased with increasing age of the crop. The content of plant nitrogen decreased with advancing age eventhough the total uptake of nitrogen showed an increasing trend from 579 g/plot at the maximum flowering to 657 g/plot at the maturity stage of the crop. Uptake of other nutrients like phosphorus, potassium, calcium and magnesium also showed an increasing trend towards the maturity stage of the crop. The ratios of these nutrients with respect to nitrogen narrowed with increase in the duration of the crop.

The total residual nitrogen status of the soil recorded a gradual increase towards the maturity stage of the crop. The value increased from 0.0514 per cent at the maximum flowering stage to 0.0558 per cent at the maturity stage. The available nitrogen status of the soil at various stages of growth of cowpea remained unaltered. The quantity of nitrogen fixed by cowpea was found to be 23, 67 and

112 kg/ha at the maximum flowering, mid pod filling and maturity stages of the crop respectively.

All these indicate that nitrogen fixing processes in cowpea are active during its entire growth period gaining pace after the maximum flowering stage of the plant.

The highest residual effect due to nitrogen fixed by cowpea was obtained from plots where it was grown upto maturity as seen from the general growth characters and fodder production of maize. Uptake of the nutrients such as nitrogen, phosphorus and potassium in fodder maize was also highest in plots where cowpea was grown upto maturity. The nitrogen made available from the decomposition of plant residues at any of the three stages of cowpea was always lower than that obtained from the addition of 30 kg N/ha. The highest fodder yield (20.7 t/ha) was obtained from plots which received an additional amount of 60 kg N/ha over and above the residual nitrogen in the soil where cowpea was grown upto maturity. The residual effect of nitrogen in the soil where cowpea was grown upto maturity was reckoned on equivalent to the effect of 60 kg N/ha.

The study has brought out the fact that maximum nitrogen gain through fixation, by growing legume crops can be achieved only if the plant is allowed to complete its full growth period.