ORGANIC MATTER AND NITROGEN RETURNS TO SOIL BY DIFFERENT CROPPING SYSTEMS ROTATIONS ON A VERTISOL IN THE INDIAN SEMI-ARID TROPICS.

BY

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THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRICULTURE

DEPARTMENT OF AGRONOMY
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CERTIFICATE

Mr. M.D. Abdurahman has satisfactorily prosecuted the course of research and that the thesis entitled " **Organic matter and nitrogen returns to soil by different cropping systems rotations on a Vertisol in the Indian semi-arid tropics**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

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This is to certify that the thesis entitled "**Organic matter and nitrogen returns to soil by different cropping systems rotations on a Vertisol in the Indian semi-arid tropics**" submitted in partial fulfilment of the requirements of the degree of "**Doctor of philosophy in Agriculture**" of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr. M.D. Abdurahman** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations has been duly acknowledged by the author of the thesis.

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I, Mr. M.D. Abdurahman declare that the thesis entitled "**Organic matter and nitrogen returns to soil by different cropping systems rotations on a Vertisol in the Indian semi-arid tropics**" submitted to Acharya N.G. Ranga Agricultural University for the degree of **Doctor of Philosophy** is a result of original research work done by me. I also declare that my material contained in the thesis has not been published earlier.

Date: 26.3.97

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Acknowledgement

I would like to express my sincere thanks to Dr. B. Bhaskar Reddy Professor and Head (I/C), Department of Agronomy, college of Agriculture, Hyderabad (ANGRAU) and Chairman of the advisory committee for his guidance and encouragement throughout my study at ANGRAU. He taught me how to always be the best student.

It gives me immense pleasure in extending my deep sense of gratitude to Dr. Charles Renard, Professor Ecologie des Grandes Cultures, Université Catholique de Louvain, Co-chairman of my advisory committee for his valuable counsel and meticulous guidance. Dr. Charles was always available when I needed his help for my work and for my personal life. My family and I will never forget your continuos support.

I would also like to thank Dr. T.J Rego Sr. Scientist, Soils and Agroclimatology Division (SACD) for his ideas and useful comments towards the research component of my studies. He never hesitated to share with me his vast experience. I certainly learned a lot from him.

My sincere thanks to Dr. Björn Seeling, Research Fallow, (SACD) for unreserved guidance and support throughout the course of this study. Owing to his red pen, this manuscript was straightened and one of my wishes came true. Thank you Dr. Seeling.

I extend my sincere thanks to Dr. P.S. Sarma Professor and Head (I/C), Department of Plant Physiology, college of Agriculture, Hyderabad (ANGRAU) and Dr. V. Satyanarayana, assistant controller examinations, members of my advisory committee for their help during my study at ANGRAU.

I am grateful to Dr. R.J.K. Myers, Director, Soils and Agroclimatology Division (SACD) for keen interest, constructive criticism and invaluable suggestions during thesis writing.

Special thanks to Dr. J.G. Ryan, Director General (DG), ICRISAT; Dr. Y.L. Nene, Deputy DG, ICRISAT, Dr. Karl Harmsen, Regional Executive Director, ICRISAT Sahelian Center, Dr. B. Diwakar, Acting Programme Leader, Training and Fellowships Programme for their help in getting the scholarship and most importantly for helping me reunite with my family. Thanks to you all, without your help and support I would not have achieved this today.

The generous help of many people during my research work must be noted. The work described here would not be as substantive as it is without the help of following people: M. Mohan Rao, T. Gopal Chary, P. Balwanth Reddy, and Yadiah, thanks to you all for your continuos help and support during field work. I will never forget those hot sunny days or rainy and cold days that we worked together in the field hammering down soil tubes. Thanks to G. Ravi Kumar and Mrs. J. Jayamani for their help in analysing plant samples and K.V.S. Murthy, O.P. Balakrishnan and J.Koteshwar Rao for analysing soil samples. Thanks to Mr. V. Nageswara Rao and Mr. G. Pardhasaradhi for their day to day support and suggestions. Thanks to Mrs. R.S. Sirisha for providing the necessary supplies and stationaries for field use and thesis writing.

I appreciate the work of SACD-Soil Chemistry, regular work force (RWF), Swamy, Shankaraiah, Pushpamma, Swaroopa, Kamalamma and Danamma. Thanks to you all for your help during plant growth sampling and processing.

I appreciate the assistance of Mr. G. Swaminathan and Mr. V.R. Prabhakar, (Statistics unit) in analysing the data.

I thank TAFP staff, S.V. Prasad Rao, Mrs. Jagatha Seetharaman and M.S. Reddy for being always helpful. They took care of me and my family. They always make sure to arrange transport for my numerous trips to ANGRAU, renew my family visa, take care of my photocopy requirements etc.

I deeply acknowledge funding of this work from the GTZ/ICRISAT. I also thank Andhra Pradesh Agricultural University (ANGRAU) now renamed as Acharya N.G. Ranga Agricultural University (ANGRAU) for giving me the admission.

Thanks to my wife Luul who was a great source of love and inspiration during all my studies, and to my lovely boys Abdi Jabar and Radwan. With their playing and hugs I was able to regain my strength after a long and tireing day in the field. They certainly make my day. I love you all.

I cannot express in words how grateful I am to my parents, who always taught me the value of education, and despite the harsh living conditions in Mombasa, they always managed to keep my moral high by sending letters. I also thank my sisters, brothers who always encouraged and supported me and took care of our parents while I was studying. I dedicate this work to you all.

During my stay at ICRISAT and India I made many friends who stood by me and supported me morally or otherwise. I particularly thank Dr. Melak Mengesha, Dr. K. F.Nwanze, Dr. Francis Nwilene, Dr. Ali-Nur Duale, Mr. Eric McGaw, Drs. Eva and Fred Rattunde, Dr. Ito, Philppe and Barbara Delfosse. I also thank my classmates Vijay Kumar, Martin, Mohanaba, Padmaja for their help and support during the course work.

My family and I would like to thank the housing office staff particularly Mrs. Swapna Shaw and Mr. Shadakshari for taking care of the maintenance of our flatlet and by being always helpful.

Finally, I give the credit to my lord for making it possible for me to pursue and complete this endeavour.

M.D. Abdurahman

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Degree to which it is submitted	:	Doctor of Philosophy
Faculty	:	Agriculture
Department	:	Agronomy
Major Advisor	:	Dr. B. Bhaskar Reddy
University	:	Acharya N.G. Ranga Agricultural University
Year of submission	:	1996

ABSTRACT

Organic matter plays an important role in improving soil fertility. After its mineralization it provides the much needed nutrient N, it also improves the soil physical properties. Therefore, it is important to quantify organic matter inputs by different cropping systems. It is equally important to know the quality of this organic matter because it helps budget the N requirement of the following crops. Therefore, an experiment was conducted at ICRISAT Asia Center (IAC) for four seasons (2 rainy and 2 postrainy seasons).

There was a significant difference in root dry matter between the crops receiving no fertilizer N and the crops receiving 80 kg N ha^{-1}. When no fertilizer N was applied the system Sorghum/Pigeonpea Sorghum/Pigeonpea (S/PP S/PP) gave highest root organic matter (2395 kg ha^{-1}), and followed by Cowpea/Pigeonpea Sorghum+Safflower (COW/PP S+SAF) (1833 Kg ha^{-1}) and the lowest root organic matter was observed in Fallow+Sorghum Fallow+Chickpea (F+S F+CKP) system and its mirror image Fallow+Chickpea Fallow+Sorghum (F+CKP F+S) (818 Kg ha^{-1}). When fertilizer N (N80) was applied, S/PP S/PP gave slightly higher root dry matter (2651 Kg ha^{-1}) than S+SAF S+SAF (1473 Kg ha^{-1}) which show that if crops are adequately fertilized even the non-leguminous system can give equally higher root dry matter. Similar observations were found in the studies of root N content.

Pigeonpea and cowpea also contribute to the organic matter pool by way of fallen dry leaves. The leaf fall in both crops start shortly before flowering and continued till harvest with the bulk of the leaf fall occurring at maturity. At harvest pigeonpea leaf fall was around 2.5 t ha^{-1} and cowpea was around 0.14 t ha^{-1}.

N uptake of the kharif sorghum was higher in 1995 compared to 1994, but in later stages of growth the N uptake of 1995 kharif sorghum reduced sharply probably due to the fall of N concentration in the plant because of the high rainfall during that period. Rabi crops N uptake was high in 1994 than 1995 because of the erratic distribution of rainfall.

COW/PP S+SAFF system was found to contribute equivalent of 40 Kg ha^{-1} of fertilizer N to the rainy-season sorghum which followed and the sorghum N uptake was increased by 20 Kg N ha^{-1}.

Nitrogen fixation estimation showed that pigeonpea could fix as high as 148 Kg N ha^{-1}, when N-difference method was used and kharif sorghum was taken as a reference crop. Other legumes such as chickpea and cowpea were found to fix between 27-75 Kg N ha^{-1}. Studies of N balance of these legume crops showed that pigeonpea gave a net positive N balance of between 88-92 Kg N ha^{-1}, whereas chickpea showed a negative N balance when sorghum was taken as a reference crop, but when safflower was taken as a reference crop it gave a positive N balance of 4 Kg N ha^{-1}. Cowpea gave a positive N balance between 3 and 20 Kg N ha^{-1}.

Soil chemical analysis show that the systems which involve legumes increased soil NO_3-N whereas non-leguminous system the fallow system did not increase the soil NO_3.

Introduction

CHAPTER I

INTRODUCTION

The total area of the semi-arid tropics (SAT) is estimated at about 19.6 million km^{2} (Virmani et al. 1988), with a population of about 900 million. It is estimated that around 20% of the SAT farmers are farming vertisols.

Vertisols are one of the major soil groups, and occur in several parts of the semi-arid tropics (SAT) (Swindale 1982). They contain at least 30% clay, and are generally deep (60 cm or more). Vertisols are therefore able to retain considerable amounts of available water in the soil profile (Kanwar and Virmani 1987). Because of the sticky nature of these soils when they are wet, it is difficult to manage them during the rainy season, therefore, fallowing the land during the rainy season followed by postrainy season cropping is the traditional practice in India. However, hydrological studies show that these soils have the potential to support double cropping or intercropping in both seasons. ICRISAT developed a vertisol technology that involves growing one crop in the rainy season and another in the postrainy season in the same piece of land. One crop can be a long duration and another short duration. These crops can be intercropped or they can be sequential crops (El-Swaify et al. 1985). One of the major constraints to the success of this technology is the need for nutrient inputs particularly nitrogen (N). Deficiency of N is universal in tropical Vertisols (Prasad et al. 1990). Indian Vertisols, in general, have less than 1% organic carbon (OC), and their total N content seldom exceeds 0.1%(Tandon and Kanwar 1984). To achieve higher productivity it is required to apply large amounts of chemical N fertilizers which can not be afforded by many farmers in the SAT. On the other hand it is too risky to apply the fertilizers because of the erratic nature of the rainfall, therefore, managing nitrogen inputs in crop production systems to achieve economic yield and environmental sustainability is a major challenge facing agriculture. Sustainability considerations mandate that alternatives to N fertilizers must be urgently sought (Bohlool et al. 1992). Use of N-efficient crops or improving effectiveness of using fertilizers has been suggested a way to manage N inputs. However, one other alternative is relying less on commercial fertilizer N and more on biological N inputs and management of the soil to improve the soil fertility (Keeney 1982).

Legumes are considered one of the important food crops in the SAT (Virmani et al. 1988), and their role as a "soil improver" has long been recognized by farmers throughout the world; this role derives mainly from the ability of legumes to fix atmospheric nitrogen in symbiosis with rhizobia (Giller 1992). Many legumes also improve soil fertility by contributing to the buildup of the soil organic matter by dropping large amounts of leaves or by way of decomposing roots.

Field experiments with a range of cropping systems are under way at ICRISAT Asia Center (IAC) for many years. One of these experiments conducted by T.J. Rego since 1983 contains a range of alternative cropping systems. Results of this experiment show promising cropping systems in terms of productivity and sustainability, but detailed studies were not carried out to quantify organic matter and N inputs of these systems. Therefore present investigation was designed with the following objectives to provide the necessary information.

Objectives

1. To quantify organic matter inputs of five different cropping systems rotations depending on N supply status.
2. To determine nutrient uptake patterns of the crops in the investigated cropping systems.
3. To quantify the nutrient (N) returned to the soil through leaf fall and roots.
4. To evaluate the availability of N returns from legumes to the following non-leguminous crops.
5. To assess the change in soil N under different cropping systems rotations.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Leguminous crops are important components in cropping systems throughout the world. Legumes, which are also an important source of protein in the human diet, can biologically fix considerable amounts of atmospheric N, depending on both species and environment, and therefore have also been an important means of increasing N fertility of soils. Fodder or green-manure legume crop can provide appreciable amounts of N to succeeding crops; while grain legumes usually do not provide as much N. These contributions would become relatively important in soils of low fertility. Even in modern agricultural systems where N fertilizer is widely used, the importance of legumes in crop rotations is still well recognized, suggesting that factors other than N_2-fixation are also important. It is universally accepted that the beneficial effects of legumes is through addition of N_2 fixed in root nodules to the plant-soil system in sole cropping, in intercropping, or in rotation (Lee and Wani 1988). Traditionally, it has been said that the major effects of legume are through maintenance of adequate soil N and contribution of available N to an associated crop or the succeeding crop. However, it has sometimes been difficult to attribute the beneficial effects solely to increased availability of N to other crops (Ketcheson 1980). The available literature was reviewed to show the importance of legumes in the crop rotations in terms of productivity, and soil improvement.

2.1. CROPPING SYSTEMS ROTATION EFFECTS

2.1.1. Nitrogen Effect

2.1.1.1. Nitrogen balance

Accurate estimation of the amount of N_2 fixed by different crops in a particular agro-ecosystem is a prerequisite for assessing and improving the contribution of biological nitrogen fixation (BNF) to a given cropping system. However, as N_2 is dependent upon physical, environmental, nutritional and biological factors (Chalk 1991; Nambiar et al. 1988) it can not be assumed that any N_2 -fixing system will automatically contribute to the N cycle. In general, many results reported in the literature do not take into account plant roots and fallen leaf material while estimating BNF, which results in underestimating the quantity of N_2 fixed.

The total amount of N in a legume crop comes either from N_2 fixation or by uptake of mineral N from the soil. In legume crops the part of the plant N is partitioned into the harvested seed and some in the vegetative parts (leaves, stems, and nodulated roots), which generally remain as crop residues (Wood and Myers 1987).

It is clear that BNF improves the N economy of the soils, but this does not mean that the legume systems always make large net contributions of N to the soil. But the N balance for a legume-cereal sequence for example will be more positive than for a cereal-cereal sequence in the same soil.

Table 1 Amounts and N fixed, P_{fix} (%), and net N balance of some legume crops as reported in the literature.

Species	P_{fix} (%)	Amount N_2 fixed kg N ha^{-1}	Net N balance kg N ha^{-1}	Reference
Pigeonpea	10-81	7-235	- 32 to +41	1,2
Cowpea	32-89	9-201	-11 to +136	3,4,5
Chickpea	8-82	3-141	-42 to +34	6
Soybean	0-95	0-450	-132 to +80	7,8,9
Groundnut	22-92	37-206	-34 to +64	10,11
Pea	23-73	17-244	-32 to +96	12

Source :

1. Kumar Rao and Dart (1987)
2. Ladha et al. (1995)
3. Dakora et al. (1987)
4. Ofori et al. (1987)
5. Awonaike et al. (1990)
6. Doughton et al. (1993)
7. Chapman and Myers (1987)
8. Chandel et al. (1989)
9. Hughes and Herridge (1989)
10. Bell et al. (1994)
11. McDonagh et al. (1993)
12. Jensen (1987)

2.1.1.2. Nitrogen Saving

There are many reports in the literature which suggest that legumes can save some N for use by the succeeding crops. Dakora et al. (1987) found that by maize after cowpea and groundnut it can be saved around 60 kg N ha^{-1}. At a medium level of fertility management, rainy season green gram or cowpea saved around 30 kg N ha^{-1} for succeeding post-rainy maize (Shinde et al. 1984).

The N requirement of maize following a sole pigeonpea was reduced by 38-49 kg N ha^{-1} compared with maize following either fallow, sole sorghum, or sorghum/pigeonpea intercrop (Kumar Rao et al. 1987). Similarly a preceding crop of pigeonpea reduced the N requirement of succeeding wheat crop by 30 kg N ha^{-1} (Narwal et al. 1983).

Singh (1983) estimated N benefits to wheat derived from various preceding legume intercrops. Comparing wheat after sole sorghum with wheat after intercrop of different legumes, he obtained N fertilizer equivalent of 3 kg ha^{-1} with soybean, 31 kg ha^{-1} with green gram, 46 kg ha^{-1} each with grain cowpea and groundnut, 54 kg ha^{-1} with fodder cowpea. Intercrops of sorghum with cowpea, groundnut, or green gram saved 18 to 55 kg N ha^{-1} for the target yield of 4.0 tonnes of the wheat that followed (Waghmare and Singh 1984).

2.1.1.3. Beneficial effect of legumes to succeeding crop

Beneficial effects of mono-and intercropped legumes on subsequent cereal crops are well-documented (Papastylianou 1988). Various factors, such as increase in organic matter, improved soil structure, and, most importantly increase in soil N, might account for this phenomenon.

There are many reports which demonstrate the effect of legumes on the productivity of the succeeding crop. Nair et al. (1979) found increase in wheat yield by 30% after a maize/soybean intercrop and 34% after maize/cowpea compared to wheat planted after sole maize. In a 3-year experiment, Legume-wheat and fallow-wheat sequences performed better than a sorghum-wheat sequence at a medium level of N management, but at a higher level of fertility management, the advantages of legumes on succeeding wheat were not clearly evident. (Shinde et al. 1984). Pearl millet (*Pennisetum glaucum*) yielded more when sown after fallow, cowpea (*Vigna unguiculata*), or green gram (*Vigna radiata*) than after maize (*Zea mays*) (Narwal and Malik 1987).

Yield was significantly increased when wheat was grown following sorghum intercropping with cowpea or groundnut compared with following sole sorghum in the previous season (Waghmare and Singh 1984). Grain yield was significantly increased in maize intercropped with black gram (*Vigna mungo*), cowpea, and green gram as compared with sole maize and maize intercropped with groundnut (*Arachis hypogaea hypogae*) (Das and Mathur 1980). Borse et al. (1983) found that pearl millet-green gram system was consistently more productive than continuous pure pearl millet.

Apart from the effect of legumes on the productivity of the succeeding crops, it has been found that they also contribute to the quality and N uptake of the succeeding crops. Higher N uptake by wheat was observed when it followed maize/groundnut or maize/soybean intercrop systems than after maize alone (Searle et al. 1981). The N uptake without fertilizer N application by a subsequent wheat crop after cropping maize was 12 kg N ha^{-1}, after maize/soybean 19 kg N ha^{-1}, after maize peanut 46 kg N ha^{-1}, and after peanut 54 kg N ha^{-1}. This shows that a subsequent crop could benefit as much from following one of the maize/legume intercropping systems with no fertilizer N applied as from planting after a sole-maize crop receiving 100 kg N.

N uptake by a succeeding crop, when 100 kg N ha^{-1} was applied to the preceding crop, was always higher following sole or intercropped cowpea. This could be due to less immobilization of the freshly applied fertilizer N by legume crop residue rich in N (Patra et al. 1989). Total N uptake in grain + straw of wheat (*Triticum aestivum*) grown after groundnuts were significantly higher than when grown after sorghum Jadhav and Koregave (1988b). Bandyopadhyay and De (1986) found that sorghum grown in a mixture with legumes (groundnut, green gram and cowpeas) took up more N than sorghum grown as sole crop. In a mixture with green gram the total N uptake by sorghum was 90 kg N ha^{-1} while with sorghum alone it was 70 kg N ha^{-1}. The per cent N in the plant derived from fertilizer was highest with sorghum alone and the lowest when grown in mixture with legumes.

In an experiment in Northern Syria, Keatinge et al. (1988) found differences in N uptake by barley, following either a legume crop or barley, indicated that the residual effects of the legume crop amounted to approximately 10 kg N ha^{-1}. Holford (1989) found that grain sorghum N uptake was enhanced following three Lucerne *Medicago sativa* rotations. Jadhav and Koregave (1988a) reported grain protein content and total N uptake in grain + straw of wheat grown after groundnuts were significantly higher than when grown after sorghum. Similar results were reported by Jadhav (1990) when wheat grown after sorghum and groundnut.

Uptake of N by wheat grown after fodder cowpea, black gram and soybean (*glycin max*) was higher than when it was grown after cereals Jain and Jain (1993). In an intercropping study with sorghum under rainfed conditions at Coimbatore, sorghum was intercropped with soybean, greengram, cowpea or sunflower (*Helianthus annus*) (Selvaraj 1978). Nutrient uptake by the component crops was estimated, cowpea and greengram did not reduce the N uptake of sorghum compared to the sole stand of sorghum. Soybean competed with sorghum but not to the extent of sunflower. The total harvest of nutrients from the soil was not very much increased by intercropping with legumes but sunflower as intercrop caused depletion. Similar results were obtained by (Ravichandran and Palaniappan 1979). On the contrary a maize/pigeonpea intercropping experiment showed greater removal of nutrients in intercropped stands than in pure stands (Sanchez 1976). Similar results were obtained in a pigeonpea (*Cajanus cajan*) based intercropping system by Soundararajan (1978).

Application of limiting nutrient, particularly N, would cause greater dry matter production and consequently deplete the soil to a greater extent (Chinnappan and Palaniappan 1980). In Castor (*Ricinus communis*) based cropping system, with sorghum and pearl millet as an intercrop, it has been found that the system produced greater amount of dry matter and removed more nutrients from the soil than the ones with legumes as intercrops. Increasing the quantity of N applied caused greater removal of nutrients by systems with millets as intercrops since millets responded to N application by increased dry matter production. Legumes did not respond much to N application and in systems with these crops, N application did not cause much variation in nutrient removal (Chinnappan and Palaniappan 1980).

In multiple cropping systems involving sequential cropping, the total nutrient requirement of the system can be obtained by simply summing up the uptake of each crop in the system. Selection of a particular system would depend on the total quantum of nutrients removed, especially in soils of low fertility. The system that would make the least demand from the soil would be preferred (Palaniappan 1988). In this context, the nutrient balance sheet approach has been used (Sadanandan and Mahapatra 1973).

Terms like " N residual effect" (De et al. 1983) and "Fertilizer N replacement value" or N equivalent (Hesterman et al. 1987) are used to describe the role of legumes in crop rotations. They refer to the amount of inorganic N required following a non-legume crop to produce another non-legume crop with an equivalent yield to that obtained following a legume (Wani et al. 1995). This comparison provides a quantitative estimate of the amount of N that the legume supplies to the non-legume crop.

The FRV methodology gives variable estimates depending on the test crop used. The N contribution from hairy vetch and big flower was estimated to be 65 and 75 kg N ha^{-1} respectively with maize as a test crop (Blevins et al. 1990).

De (1980) evaluated residual N of various legume-based intercrop systems and found that in all treatments of black gram intercropped with either maize or sorghum improved succeeding wheat yields. In Cyprus, a semi-arid region, Papastylianou (1990) examined the response of a mixture of oats (*Avena sativa L.)* and two legumes, vetch (*Vicia sativa L.)* and Peas (*Pisum sativum L.)*, to N fertilization and the residual effect on subsequent barley (*Hordeum vulgare L.)*. He reported that grain and N yields of the barley crop were higher after the legumes than after oats, with intermediate yields after the mixtures.

Rainy season grain legumes showed appreciable residual and cumulative effects on N concentration in an unfertilized wheat crop (Dhama and Sinha 1985). Cowpea and groundnut sole crops have been shown to benefit the succeeding maize crop in terms of increased grain and dry-matter yields equivalent to 60 kg N ha^{-1} supplied through fertilizer (Dakora et al. 1987). At a medium level of fertility management, rainy season green gram or cowpea provided 30 kg N ha^{-1} for succeeding post-rainy maize (Shinde et al. 1984).

The N requirement of maize following a sole pigeonpea (*Cajanus cajan*) was reduced by 38-49 kg N ha^{-1} compared with maize following either fallow, sole sorghum, or sorghum/pigeonpea intercrop (Kumar Rao et al. 1987). Similarly a preceding crop of pigeonpea reduced the N requirement of succeeding wheat crop by 30 kg N ha^{-1} (Narwal et al. 1983).

Singh (1983) estimated N benefits to wheat derived from various preceding legume intercrops. Comparing wheat after sole sorghum with wheat after intercrop of different legumes, he obtained N fertilizer equivalent of 3 kg ha^{-1} with soybean, 31 kg ha^{-1} with green gram, 46 kg ha^{-1} each with grain cowpea and groundnut, 54 kg ha^{-1} with fodder cowpea. Intercrops of sorghum with cowpea, groundnut, or green gram saved 18 to 55 kg N ha^{-1} for the target yield of 4.0 tonnes of the wheat that followed (Waghmare and Singh 1984).

Singh and Ahuja (1990) found that sorghum grain yield increased appreciably due to the association of legumes especially cluster bean (*Cyamopsis tetragonoloba*) followed by cowpea, compared with sorghum in pure stands. Response studies suggested an advantage equivalent to about 40 kg N/ha to sorghum from the soil incorporation of legumes.

The magnitude of the residual N effect on a succeeding crop depends on the preceding cropping system, preceding legume species, and succeeding crop species and the method of estimation. In most cases in the SAT, the contribution by legumes of residual N to the succeeding crop has been estimated to be 30 to 70 kg N ha^{-1} (Lee and Wani 1988).

2.1.1.4. Beneficial effect of intercrop legumes to companion crops (current season)

Evidence of N transfer from legume to cereal has been reported by some researchers. The main pathway of N transfer may be as sloughed-off roots, N excretion from legume roots, and decomposition of nodules (Lee and Wani 1988). In 3-year N balance study, Simpson (1976) estimated that 20% of total nitrogen in subterranean clover (*Trifolium subterraneum*), 6% of that in white clover (*Trifolium repens*), and 3% of that in lucerne were transferred to the associated grass, cockfoot (*Dactylis glomerata*). Substantial N transfer from component legume to associated cereal was observed in wheat/gram and maize/cowpea mixed cropping system (Patra et al. 1986).

Remison (1978) found a 72% increase in intercrop maize grain yield over that of sole maize in a maize-cowpea combination, and Waghamare et al. (1982) observed an increase in grain yield and grain protein of intercrop sorghum when grown with green gram, groundnut, soybean, or cowpea. Brophy and Heichel (1989) observed a release of 10.4% of symbiotically fixed N in soybean (*Glycine max (L.)* Merr. Cv. Fiskeby). Release of about 30% of fixed N by the soybean root system into the nutrient culture medium has been observed by (Ofosu-Budu et al.,1993). They also found that 10% of the N released was in ureide form at the different growth stages studied. They suggested that some of the recently fixed N is released, although no direct relationship between ureide excretion and dinitrogen fixation was observed. Ledgard et al. (1985) used a new method in which subterranean clover was labeled with ^{15}N by foliar absorption, and the transfer of N from the subterranean clover to the associated ryegrass (*Lolium rigidium*) was measured. Over a 29 day period, 2.2% of the N from the subterranean clover was transferred to the ryegrass. This study suggests that N from the legume can be transferred to the associated nonlegume during the same growing season. However, the amount of N transferred does not seem to have been substantial. Agboola and Fayemi (1972) observed that early maturing legumes, such as green gram, improved yields and N nutrition of associated maize in the current season, and some of the N fixed by green gram was released into the root zone. Such benefits were not observed with late-maturing crops such as cowpea. Nitrogenous compounds such as amino acids, proteins, and peptides were identified in leachates from root zones of legume seedlings grown under sterile conditions (d'Arcy 1982; Wacquant et al. 1989).

Most of the reports on N fixation by the legumes and its transfer to the associated crops suggest that there is little evidence of direct transfer of N form the legume to the non-legume crops in the same season. It can be concluded that direct transfer of N from legume to non-legume may not occur under all conditions or might only occur slowly with time.

2.1.2. Cropping systems rotations benefits other than nitrogen (Non-N effects)

Non-N rotational benefits of the legumes to yield of subsequent crop have been demonstrated by many researchers (Cook 1988; Danso and Papastylianou 1992; Peoples and Craswell 1992; Weil and Samaranayake 1991).

Crop rotations increased the availability of nutrients other than N through increased soil microbial activity (Kucey et al. 1988; Ladha et al. 1989). Improvements in the soil structure following legumes, mainly improve soil aggregate formation, after three years of alfalfa, clover and hairy vetch mixture (Latif et al. 1992) or with numerous years of a sod pasture, or hay crop (Olmstad 1947; Power 1990; Strickling 1950) have been observed. Incorporation of legume residues improved soil water-holding capacity (Wani et al. 1994b) and buffering capacity (Buresh and De Datta 1991).

Legumes improve soil physical properties by degradation of soil clods or by the penetration of their taproot system into the soil profile, improving soil tilth and water infiltration and thus benefiting the growth of succeeding crops. Microbiological processes are involved in the degradation of soil clods, even though the mechanisms and effects of degradation are not well understood (Hoshikawa 1991).

Ries et al (1977) suggested that growth promoting substances in legume residues are responsible for the rotation effect. The rotations break the cycles of cereal pests and diseases, and phytotoxic and allelopathic effects of different residues (Francis et al. 1986).

There are other secondary beneficial effects such as improved P solubility due to blockup of fixation sites by organic materials. Also accumulation and recycling of elements other than N like P.

2.2. Changes in soil total N caused by rotations

Legume-based pasture systems can be very successful in increasing total (organic) soil N (Dalal et al. 1994). Annual increments of soil N of between 25 and 100 kg N ha^{-1} appear to be common in subterranean clover-based pastures (Simpson et al. 1973), but average rates of soil N accretion much greater than 100 kg N ha^{-1} have been reported under lucern despite the removal of large amounts of shoot N by grazing animals or as hay (Gault et al. 1995; Holford 1981).

Effects of annual crop legumes on soil N are not so clear cut (Peoples at al. 1995). A number of trials (Dalal et al. 1994; Reeves et al. 1984; Strong et al. 1986) were unable to detect consistent effects of prior legume crop on levels of total soil N. On the other hand several other researchers reported increase in soil total N. Rowland (1987) reported that total soil N increased in long-term lupin (*Lupinus sp.*)-wheat rotations. After 4 years of continuous crop rotation, the total N increased in soil under all rotations in which legume was included but not in a maize-wheat-fallow system, with the maximum buildup of N observed in rotations with groundnut (Thind et al. 1979). Intercropping of maize with black gram, green gram, groundnut or cowpea was found to increase the soil N content more than did maize alone; in general, in soils with lower levels of N, inclusion of legumes resulted in increased soil N content (Gangwar and Kalra 1980).

The total N contents of the soils were significantly increased due to the inclusion of groundnut or chickpea in the crop sequences (Sonar and Zende (1984). Deka and Singh (1984) found that total nitrogen content of soil increased in all the rotations except in pure cereal (rice-wheat), maximum being in rice-berseem. Among individual crops berseem proved most efficient in building up soil total N. Jadhav (1990) Studied the effects of crop sequence and N fertilizer levels under groundnut-wheat and sorghum-wheat cropping systems. Total N increased as compared with the sorghum-wheat system.

Patwary et al. 1989 investigated the soil nitrogen balance for cropping systems with or without a legume component in the rotation. The contribution of biologically fixed atmospheric nitrogen from chickpea and lentil to the following cereal was estimated. The maximum net gain in total N (50 kg ha^{-1}) was achieved with a soybean - rainy season rice - autumn rice rotation followed by wheat - mung - autumn rice (38 kg ha^{-1}) and soybean - jute - autumn rice (27 kg ha^{1}). The mean values of total N in soil showed a deficit balance in fallow - jute - autumn rice and wheat - fallow - autumn rice rotations to the extent of 41 and 19 kg N ha^{-1}, respectively.

Mostly it is difficult to observe the net effects of crop legumes on total N, Peoples et al. (1995) state a number of reasons. However, there may be more appropriate indices of the benefits of legumes on the soil N pool than measurement of total soil N. A number of rotational trials have demonstrated that legumes can increase the capacity of soils to supply plant-available N regardless of whether there are detectable changes in soil reserves or not. The ability of legumes to improve soil reserves of readily mineralizable organic N have been reported for crop legumes (Dalal et al. 1994; Herridge et al. 1993), temperate and tropical pasture species (Bromfield and Simpson 1973; Dalal et al. 1994; Thomas and Lascano 1994).

2.3. Changes in soil nitrate N caused by rotations

One of the most consistent effects of both crop and pasture legumes is to increase plant-available (nitrate) N in the soil. Such effects are reported in the literature as mentioned in (Table 2)

Table 2. Examples of the increased levels of soil nitrate often detected after growth of a legume

Species	Additional soil nitrate kg N ha^{-1}		Reference
	Post-harvest	Pre-sowing	
Chickpea	+14	+46	Herridge et al. (1994)
Soybean	+23	+62	Herridge (1987)
Green gram	+26	+57	Doughton and Mackenzie (1984)
Black gram	+38	+68	Doughton and Mackenzie (1984)

In the studies summarized in Table 2 nitrate N levels in soil immediately following legumes were 14 to 38 kg N ha^{-1} greater than the levels after non-legumes. This extra nitrate, detectable even during growth of the legume, results from a reduced use of soil nitrate " nitrate -sparing"(Evans et al. 1991; Herridge et al 1994; Herridge and Bergerson 1988), the possible release of products of N_2 fixation from nodulated roots (Ofosu et al. 1992; 1993, Poth et al. 1986; Sawatsky and Soper 1991), or from N mineralized from fallen leaves or roots and nodules lost during growth and development (Peoples et al. 1995). After a period of time the differences in levels of soil nitrate between legume and non-legume plots usually increase as N contained in the legume residue is released.

At ICRISAT-Asia Center, Patancheru, India, a long term rotation experiment is being conducted on a vertisol since 1983 using two year crop rotation treatments. The surface soil (0-20 cm) samples collected after harvest of 9th season crop show in general higher amounts of mineral N contents in the soil from the legume-based cropping system than the non legume based cropping system (Rego and Seeling 1994). Inclusion of green gram in the cropping sequence increased available nitrogen in the soil at harvest to the extent of 12.6% in the non-fertilized control plot (Rao and Singh, 1991). Similarly, higher mineral N content in the soil under a eight year rotation using faba beans was observed than under continuous barley treatments (Wani et al. 1991a; 1991b).

In addition to mineral N content in the soil , N mineralization potential (N_o) of the soil under pigeonpea-based cropping systems was almost two times higher as compared to fallow-sorghum treatment (Wani et al. 1995). In a long-term rotation experiment being conducted at ICRISAT-Asia Center, Patancheru, India, soil samples were collected prior to the start of the experiment in 1983 and later in 1993, the results show that in the case of Fallow+Sorghum system, Sorghum+Chickpea-Sorghum+Safflower and Sorghum+Safflower-Sorghum+Safflower total soil N content decreased after 10 years. The continuous greangram+sorghum maintained the soil N while substantial increase in total N was observed in Sorghum/Pigeonpea-Sorghum/Pigeonpea and Cowpea/Pigeonpea-Sorghum+Safflower systems (Rego and Seeling 1994).

In an experiment Patil and Mahendra (1988) found that sole pearl millet did not increase the soil N but the intercrops involving clusterbean and cowpea raised the nitrate nitrogen content of the soil. Jadhav and Koregave (1988a) estimated that a saving of 25.75 kg N ha^{-1} in the fertilizer rate for wheat can be achieved by growing it after groundnuts.

Few studies have attempted to quantify the relative benefits of fixed or spared N, but on investigation Chalk et al. (1993) concluded that in the case of a lupin crop, fixed N from fallen leaves and roots, and unutilized soil nitrate contributed in approximately equal proportions of the N benefit to a subsequent cereal crop. However, another study of the residual benefit of vetch (Danso and Papastylianou 1992), attributed the 61% improvement in N accumulated in barley following vetch compared to barley after oats, to a reduced uptake of soil N by vetch rather than a release of fixed N.

The combination of conserved soil N, greater mineralization potential and return of fixed N might explain why the benefits of crop legumes to subsequent non-legume crops can be considerable (Doyle et al. 1988; Peoples and Craswell 1992; Wani et al. 1995). However, rotational benefits might be greater than expected from calculations of the apparent return of fixed N to the soil because estimates of N_2 fixation have almost always been solely on measurements of shoot N. The contribution of roots and nodules have often been overlooked as potential source of N. Estimates of amounts of N present in nodulated roots determined from field excavation of root systems of various crop legumes have ranged from <15 kg N ha^{-1} (Bergersen et al. 1989; Kumar Rao and Dart 1987) to between 30 and 50 kg N ha^{-1} (Chapman and Myers 1987; Unkovich et al. 1994).

2.4. Role of legumes in improving soil organic matter

Organic matter is important for crop production. Unfortunately, crop production often decreased soil organic matter content. Crop rotation affects soil organic matter in several ways. Factors affecting it include rotation length, losses caused by tillage operations, mineralization, and interaction with fertilization practices.

Crop rotations that involve long periods of sod, pasture or hay crops usually increase soil organic matter content during the sod, pasture or hay period, and that increase affects subsequent crops beneficially and probably contributes to the rotation effect. In contrast, most reports indicate that short rotations, such as maize-soybean as compared to continuous maize, result in a decrease in soil organic matter even though they do provide a positive rotation effect (Dick et al. 1986).

Sonar and Zende (1984) studied crop rotations involving different grain legumes and different levels on N in two types of soils; of a deep black calcareous clay loam (Typic Chromusterts) and on a non-calcareous medium black sandy clay loam soil (typic Ustochrept) were studied for two years. They found that at the end of the rainy season groundnut caused a significant increase in organic carbon (C) content of the soils as compared to that of sorghum and pearl millet sequence. Cropping sequences involving either groundnut or chickpea maintained the organic C status of the soil at a higher level, whereas sequences without legumes resulted in reduction of organic carbon in both the soils.

Deka and Singh (1984) found that organic carbon content of soil increased (0.53 to 0.85%) in all the rotations except in pure cereal (rice-wheat), maximum being in rice-berseem. Among individual crops berseem proved most efficient in building up of soil organic carbon.

In an experiment Patil and Mahendra (1988) found that sole pearl millet did not increase soil organic C, but the intercrops involving clusterbean and cowpea raised the organic C content of the soil from 0.55% to 0.86. The effects of crop sequences were assessed under groundnut-wheat and sorghum-wheat cropping systems.

Holford (1990) investigated organic carbon levels during 8-year rotations of grain sorghum (4 years) with lucerne (4 years), annual legume (faba beans or cowpeas in alternate years), wheat (4 years) and long fallow (alternate years) on a black earth and a red clay in northern New South Wales. In comparison with continuous cereal growing, the annual legume rotation had no significant effect on organic carbon. Gaikwad et al. (1994) found that OC increased in the rotations involving legumes.

A six-growing season study in Thailand showed improvement of soil organic matter under mixed cropping. Soil organic matter content in a maize/ricebean intercrop study doubled to 1.6% over this period, while it changed only slightly, from 0.83% to 1.10%, under green gram after a maize cropping system (Phetchawee et al. 1986).

In general most of the short term rotations do not increase soil organic matter. However, if the treatments are repeated over a long period of time, there could be a change in the soil organic matter.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS:

3.1 Experimental Site

The experiment was conducted at ICRISAT Asia Center (IAC), India during 1994-1996 in four seasons (two rainy seasons and two post-rainy seasons) The site is located at 18° N, 78° E, in Patancheru Village, 26 Km northwest of Hyderabad (State of Andhra Pradesh) at an altitude of 545 m above sea level (ICRISAT 1985).

3.2 Climate

3.2.1 Climate of the Semi-Arid Tropics

The climate of ICRISAT Asia Center is typical of Semi-Arid Tropical environment characterized by a short rainy season (3-4 months) and prolonged dry weather (8-9 months).(ICRISAT 1989).

Three distinct seasons characterize this environment:

- o Kharif or monsoon season, usually begins in June and extends into early October during which more than 80% of the total annual rainfall (760 mm) is received. In this season rainfed crops are raised.

- Rabi or the post-rainy season (mid-October through January), is dry and relatively cool, and days are short. During this period, crops can be grown on vertisols using stored soil moisture.
- Summer, the hot season begins in February and lasts until rains begin in June; crops grown in this season require irrigation.

The mean annual maximum temperature is 35.5°C and the minimum is 18°C. The average daily pan evaporation varies from 3.8 to 12.3 mm (ICRISAT 1989).

3.2.2 Climatic conditions during the experimental period

In 1994 kharif season rainfall was adequate and its distribution was uniform during crop establishment stage, therefore there was uniformity in crop growth. The same trend continued during rabi season. There were no rains in the final six weeks of the year, which is desirable because it coincides with the crop maturity. In the second year rainfall was high which resulted in poor emergence of the crop.

Figure 1 shows rainfall, maximum and minimum temperature during crop growth period, and Appendix 1 shows detailed climatic data of the same period.

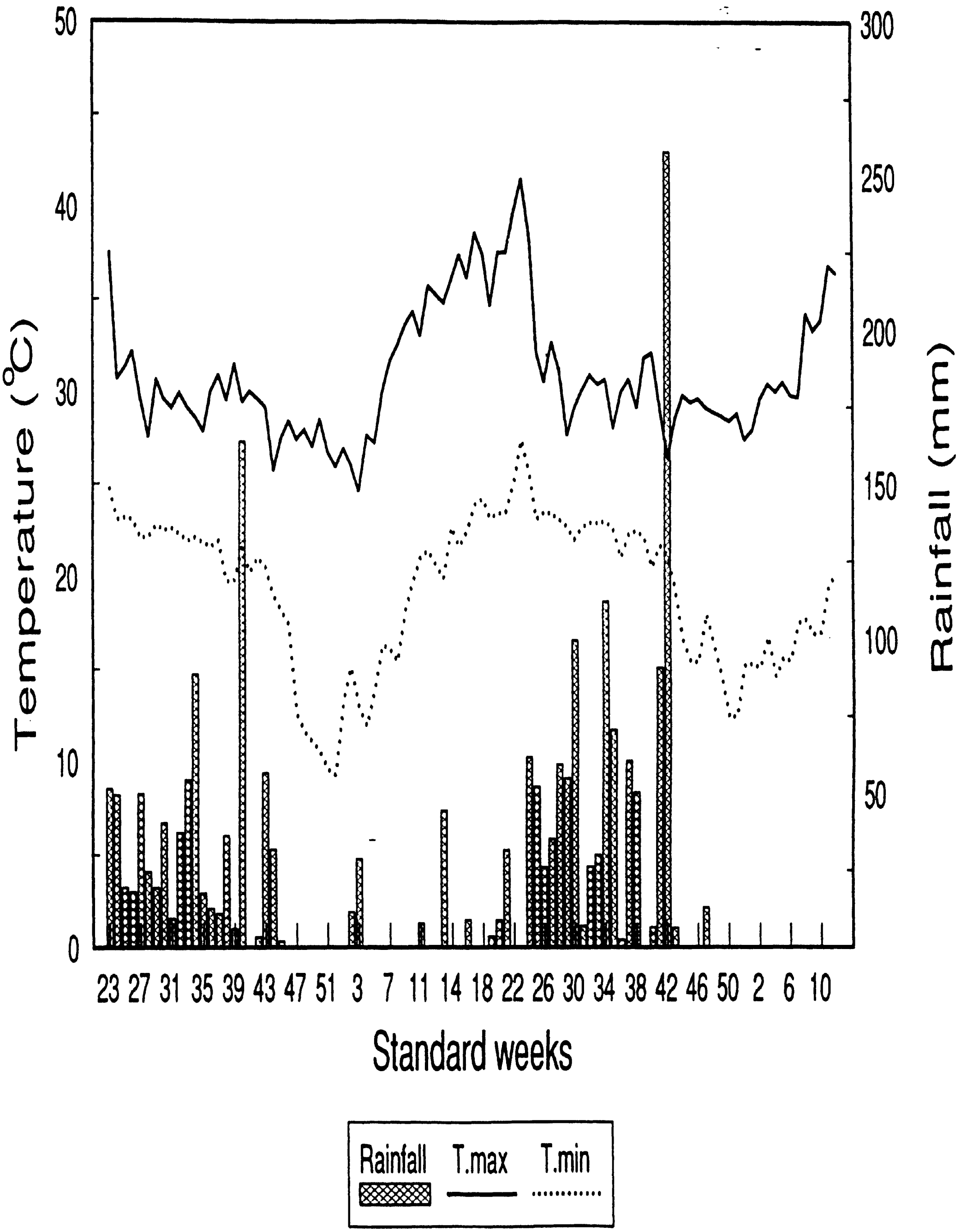

Figure 1 Rainfall and temperature during crop growth period.

In the second year, there was a heavy infestation of Helicoverpa in pigeonpea which resulted in poor grain yield, despite taking adequate protection measures against it (Plate 2)

3.3 Soil:

The field used was deep vertisol located in ICRISAT watershed area (BW3-F1), with initial nutrient status as in Table 3.

Table 3. Initial fertility status of the field BW3-F1.

Parameters tested	Depths (cm)				SE±
	0-15	15-30	30-60	60-90	
pH	8.19	8.33	8.39	8.23	0.045
EC (d S m^{-1})	0.26	0.17	0.16	0.23	0.013
NO_3 (mg kg^{-1})	2.67	<1	<1	<1	0.19
TOTAL N (mg kg^{-1})	639.3	433.7	369.7	331.3	12.72
OC (%)	1.62	0.47	0.44	0.39	0.016

3.4 Experimental Details :

1. Experimental Design and Treatments:

The treatments were six cropping systems and three levels of nitrogen. The design is randomized complete block design (RCBD).

The treatments are :

A. Cropping Systems:

	I Year	II Year	Abbreviation
1.	Sorghum/Pigeonpea	Sorghum/Pigeonpea	S/PP S/PP
2.	Sorghum + Safflower	Sorghum + Safflower	S+SAF S+SAF
3.	Cowpea/Pigeonpea	Sorghum + Safflower	COW/PP S+SAF
4.	Sorghum + Safflower	Cowpea/Pigeonpea	S+SAF COW/PP
5.	Fallow + Sorghum	Fallow + Chickpea	F+S F+CKP
6.	Fallow + Chickpea	Fallow + Sorghum	F+CKP F+S

/ = Intercropping + = Sequential cropping

B. Nitrogen Levels (applied to only non-legume crops)

1. 0Kg N ha^{-1}
2. 40 Kg N ha^{-1}
3. 80 Kg N ha^{-1}

5 Sor+Saff **Sor+Saff** N=40	10 F+Ckp **F+Sor** N=80	15 Sor/PP **Sor/PP** N=80	**D**	23 Sor+Saff **Sor+Saff** N=0	28 Sor/PP **Sor/PP** N=80	33 Sor+Saff **Sor+Saff** N=40	**D**	42 F+Ckp **F+Sor** N=40	47 F+Sor **F+Ckp** N=0		
4 Sor+Saff **Sor+Saff** N=80	9 F+Ckp **F+Sor** N=40	14 Sor+Saff **Cop/PP** N=40	**D**	22 F+Ckp **F+Sor** N=80	27 F+Sor **F+Ckp** N=80	32 F+Sor **F+Ckp** N=0	37 F+Sor **F+Ckp** N=80	41 Cop/PP **Sor+Saff** N=40	46 Sor/PP **Sor/PP** N=80	51 Sor+Saff **Cop/PP** N=80	
3 Sor+Saff **Sor+Saff** N=0	8 Sor/PP **Sor/PP** N=40	13 Sor+Saff **Cop/PP** N=80	18 F+Sor **F+Ckp** N=80	21 Sor+Saff **Sor+Saff** N=80	26 Sor+Saff **Cop/PP** N=80	31 F+Sor **F+Ckp** N=40	36 Sor+Saff **Cop/PP** N=0	40 Cop/PP **Sor+Saff** N=0	45 Sor+Saff **Sor+Saff** N=80	50 Sor/PP **Sor/PP** N=40	54 Cop/PP **Sor+Saff** N=80
2 F+Sor **F+Ckp** N=40	7 Sor+Saff **Cop/PP** N=0	12 Cop/PP **Sor+Saff** N=40	17 Cop/PP **Sor+Saff** N=80	20 Sor+Saff **Cop/PP** N=40	25 Cop/PP **Sor+Saff** N=40	30 Sor/PP **Sor/PP** N=0	35 F+Ckp **F+Sor** N=0	39 F+Ckp **F+Sor** N=0	44 Sor/PP **Sor/PP** N=0	49 Sor+Saff **Cop/PP** N=40	53 Sor+Saff **Sor+Saff** N=40
1 F+Sor **F+Ckp** N=0	6 Sor/PP **Sor/PP** N=0	11 F+Ckp **F+Sor** N=0	16 Cop/PP **Sor+Saff** N=0	19 Cop/PP **Sor+Saff** N=0	24 Cop/PP **Sor+Saff** N=80	29 F+Ckp **F+Sor** N=40	34 Sor/PP **Sor/PP** N=40	38 F+Sor **F+Ckp** N=40	43 F+Ckp **F+Sor** N=80	48 Sor+Saff **Sor+Saff** N=0	52 Sor+Saff **Cop/PP** N=0

Road

RI **RII** **RIII**

A) Cropping Systems (6)

I YEAR	II YEAR
1) Sorghum/Pigeonpea	Sorghum/Pigeonpea
2) Sorghum + Safflower	Sorghum + Safflower
3) Cowpea/Pigeonpea	Sorghum + Safflower
4) Sorghum + Safflower	Cowpea/Pigeonpea
5) Fallow + Sorghum	Fallow + Chickpea
6) Fallow + Chickpea	Fallow + Sorghum

B) "N" Levels

1) Zero (0)
2) 40 Kg N ha^{-1}
3) 80 Kg N ha^{-1}

Plot area= 12 x 12 m
8 beds/plot

Sor= Sorghum
Ckp= Chickpea
Cop= Cowpea
PP = Pigeonpea

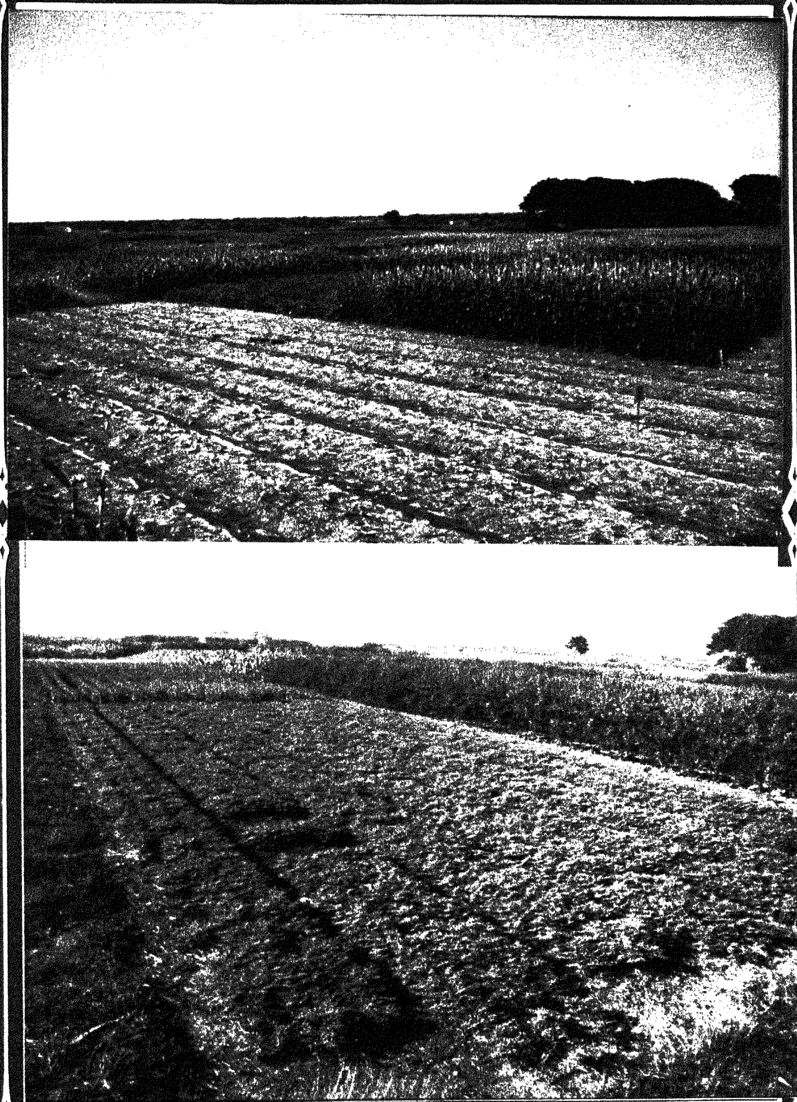

Plate 1: An overview of the field during kharif (above) and Rabi (below).

Plate 2: Pigeonpea, chickpea and safflower were sprayed against Helicoverpa.

The plot size was 12×12 m, and the broadbed and furrow system was used, in which each plot consists of 8 beds. The bed width is 150 cm (150 cm × 8 beds = 12 m). and the row length was 12 m, therefore the total area of the plot is 144 m^2.

The intercrops were:

A. Sorghum/Pigeonpea : Consists of 2 rows of sorghum on either side and a row of pigeonpea in the center. The spacing was 75 cm between the two sorghum rows and the spacing between plants was 10 cm.

B. Cowpea/Pigeonpea : consists 2 rows of cowpea on either side and a row of pigeonpea in the middle. The spacing was 75 cm between the two cowpea rows and the spacing between plants was 10 cm.

Crops and varieties used were:

		Sown	Harvested
A.	*Kharif Crops:*		
1.	Sorghum (CSH-6)	13 June1994	10 Oct. 1994
		15 June 1995	12 Oct.1994
2.	Pigeonpea (ICP1-6)	13 June1994	23.Jan. 1995
		15 June1995	5 Feb. 1996
3.	Cowpea (GC 82-7)	13 June 1994	1 Sept. 1994
		15 June 1995	2 Sept. 1995
B.	*Rabi Crops:*		
1.	Sorghum (SPV 421)	19 Oct. 1994	21 Feb. 1995
		15 Oct. 1995	30 Jan. 1996
5.	Safflower (Manjera)	20 Oct. 1994	7 March 1995
		15 Oct. 1995	13 Feb. 1996
6.	Chickpea (Annegiri)	20.Oct. 1994	6 Feb. 1995
		20 Oct. 1995	2 Feb. 1995

3.5 Field Operations:

The field BW-F1 located at a vertisol watershed of ICRISAT Asia Center (IAC), had been fallowed for 7 years before the start of this experiment. Maize crop was grown as a cover crop before the start of the experiment. All the operations were carried out with bullock drawn equipment. Weeding was done by hand. In the first year the field was weeded four times, whereas in the second year it was weeded twice.

3.6 Sowing and Fertilizer Application:

Sowing was carried out with bullock-drawn equipment, whereas fertilizer was applied manually in bands. The dose was split into two applications. Kharif crops received an initial dose of 20 Kg N ha^{-1} at the time of sowing, where applicable, the rest was given 21-24 days after sowing (DAS). Rabi crops received the whole fertilizer dose at the time of sowing . The nitrogen was given only to non-legume crops. In intercrops it was applied banded to the non-legume. All crops received phosphorus fertilizer uniformly at a rate of 20 Kg P ha^{-1}, and it was applied at the time of sowing.

3.7 Observations and Measurements:

3.7.1. Plant Dry Weight:

An area of 1 m^2 was marked, and plants in that area were cut (Plate 3). Sample plants were separated into leaves, stems, heads or pods, and all parts were oven dried at 60°C to constant weight is obtained. The dry weights were recorded. The dry plants were then ground prior to laboratory analysis. In 1994 growth samples were taken in a 15 days interval, but in 1995 a sample was taken in every 3-4 weeks.

3.7.2. Root Sampling:

Root samples were taken from the same 1 m^2 area where the plants were cut, but only from zero plots and 80 Kg N ha^{-1} plots. Soil cores of 7 cm diameter (Plate 4 and 5) were taken to depths of 120 cm for all crops except for pigeonpea which was sampled to 150 cm. The core sampling was done with metal tubes of 7 cm diameter. Two cores were taken from between rows and 2 cores in rows between the plants (Plate 6). A fifth was taken on top of one plant in each crop.

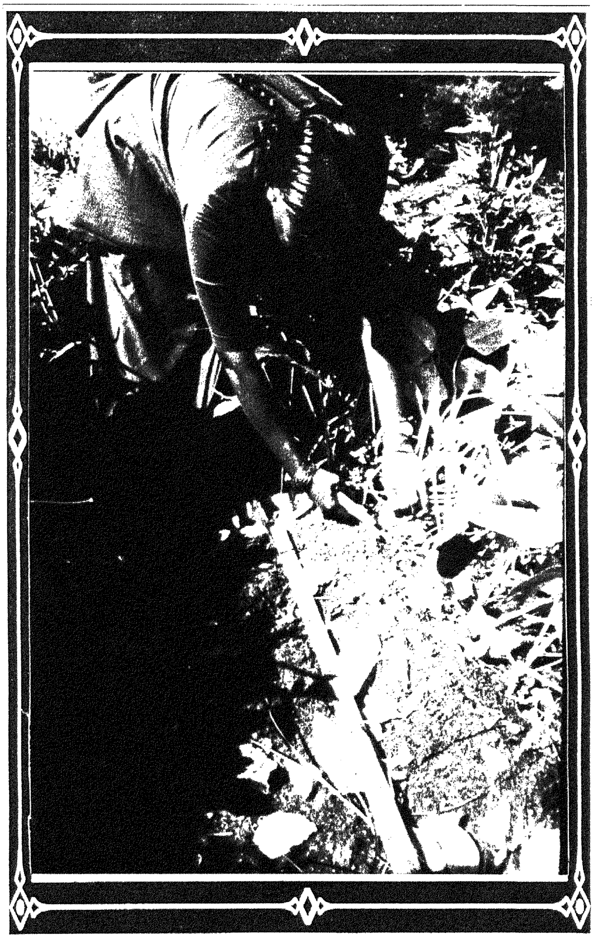

Plate 3: Plant samples were taken from an area of 1 m^2. Plants were cut from the base of the stem to avoid lose of dry matter.

Plate 4: Root sampling tubes.

Plate 5: Root samples being taken from cowpea plots.

Plate 6: Root sampling area after the samples were taken.

Samples were combined and were soaked in water over night, and then washed over a sieve of fine mesh, then the roots were hand picked and put in a bottle containing a mixture of ethyl alcohol and water at the ratio of 2:1, to facilitate longer storage and were kept in a cold room. Then the fresh weights of the total root samples were taken after properly drying them with filter paper. After that the root length of the total sample was determined using a Comair root length scanner. After that the roots were oven-dried at 60°C to constant weight, and dry weights were determined.

3.7.3. Collection of Fallen Dry Leaves of Cowpea and Pigeonpea

At weekly intervals, fallen leaves of pigeonpea and cowpea was collected from an area of 1 m × 1.5 m which was surrounded by plastic sheets (Plate 7 and 8). Collected leaves were then oven dried at 60°C, and their dry weights recorded. Later the leaves were ground for chemical analysis.

3.8. Plant Chemical Analysis:

Nitrogen concentration was determined in individual plant parts by Kjeldahl digestion followed by colorimetry, using a Technicon Autoanalyser (Technicon Industrial System 1994).

Plate 7: Fallen dry leaves of pigeonpea (above) and cowpea (below) were collected from an area of 1 m^2, surrounded by plastic sheets.

Plate 8: Fallen leaves of pigeonpea besides being a source of organic matter it can also act as a mulch.

3.9. Soil Chemical Analysis:

At the end of the second year of cropping soil samples were taken from all the plots. Ten cores to a depth of 150 cm were taken from each plot. Samples were analyzed for soil total N by Kjeldahl digestion followed by distillation and titration and mineral (NH_4 and NO_3) N by distillation and titration by 2M Kcl extracts (Keeney and Nelson 1982).

3.10 Statistical Analysis :

The data of the experiments were subjected to the analysis of variance (ANOVA) using a randomized complete block design (RCBD) in the case of growth samples which were collected from N0 and N80 plots, and RCBD factorial design analysis in the case of soil and final yields. The data was analyzed using the GENSTAT package for statistical analysis Gomez and Gomez (1984).

RESULTS

CHAPTER IV

RESULTS

4.1. Quantification of organic matter inputs of different cropping systems rotations at different N levels.

4.1.1. Root Organic Matter Inputs

In the S/PP S/PP system sorghum is intercropped with pigeonpea in both years, only the sorghum received fertilizer N. In 1994 root samples were taken from depth of 0-90 cm, in 15 cm intervals. There was no significant difference in root dry matter of the fertilized and non-fertilized sorghum in the initial stages of plant growth (till 60 DAS) but in later stages of growth, the sorghum crop which received 80 kg N ha^{-1} had significantly higher root dry matter than the N0 plot. (Figure 2). The highest root dry matter (1021 kg ha^{-1}) was obtained at 72 DAS and later total root mass decreased. Most of the root mass (75-80%) was found in the upper layer (0-30 cm) of the soil. The intercropped pigeonpea did not receive any nitrogen fertilizer since it was applied in bands close to the sorghum rows. The highest pigeonpea root dry matter (1334 kg ha^{-1}) was recorded at 108 DAS (Figure 3). Most of the root dry matter (70%) was found in the upper layer of 0-30 cm, but roots were found growing up to 90 cm depth, which was maximum sampling depth.

In the second year (1995), the same treatments were repeated in this system S/PP S/PP. In this year root sampling depth has been increased to 150 cm with 15 cm intervals. Again sorghum roots showed higher growth rate in the initial stages of growth.

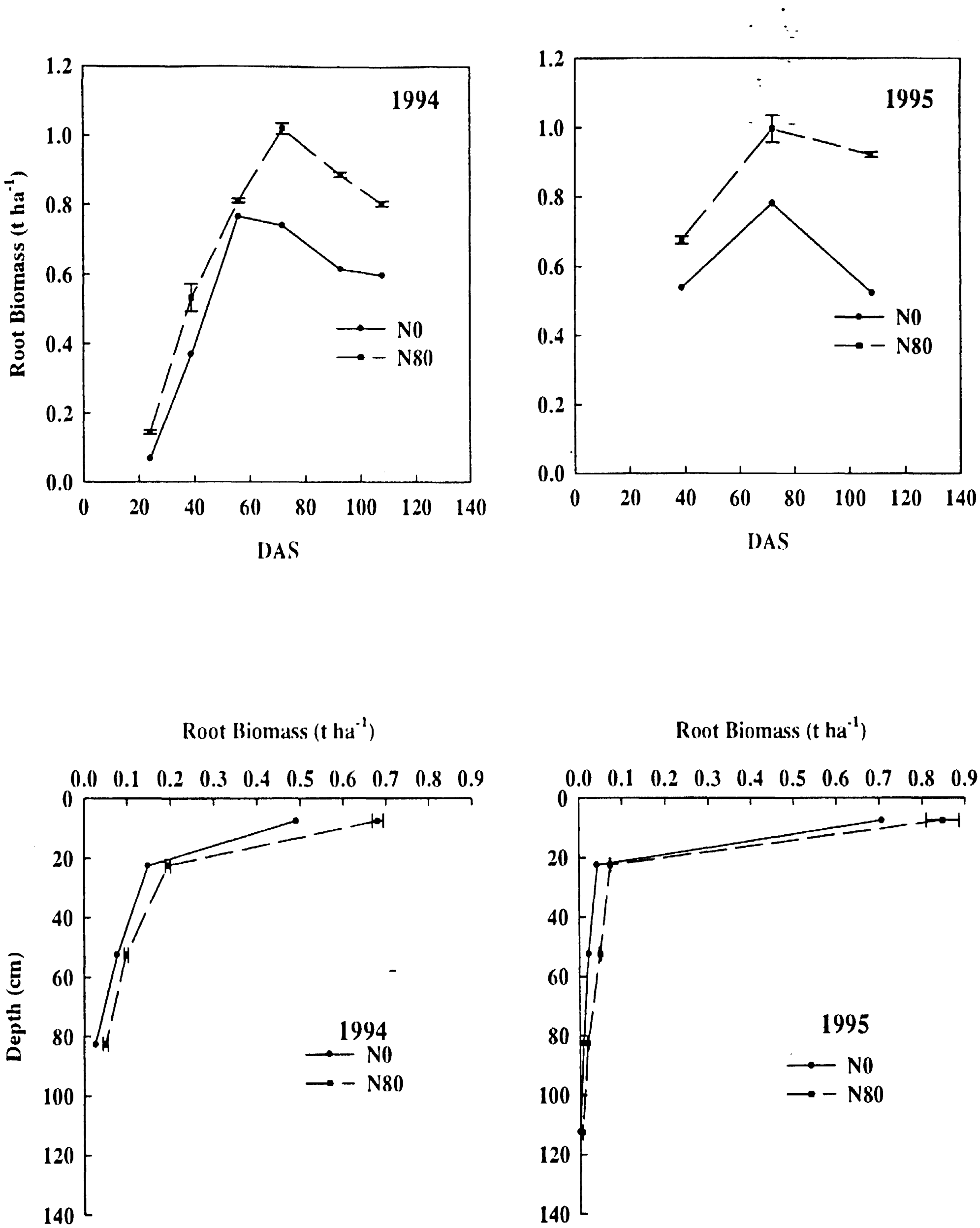

Figure 2 Root biomass of rainy season sorghum in S/PP intercropping systems and its root biomass distribution in the soil profile at maximum root biomass.

Maximum root dry biomass was obtained at 72 DAS (Figure 2). Pigeonpea root growth rate in the second year was slower compared to the first year. Maximum root biomass (1189 kg ha^{-1})was recorded at 147 DAS (Figure 3). In the second year pigeonpea maximum root dry matter was obtained in a later period than in the first year. This could be due to the slower growth rate of the roots in this year, therefore maximum root dry matter period was reached in 147 DAS.

In the system S+SAF S+SAF, which is a non-legume system, the crops were grown as sole crops. Fertilizer N was applied only to the N treatment plots. Sorghum plants which received 80 kg N ha^{-1} had significantly higher root biomass than the crop with zero N in both years. In 1994, highest root biomass of sorghum was obtained at 72 DAS (Figure 4). In the second year of the experiment (1995), the same crops were repeated in this system S+SAF S+SAF. In this year, difference in root dry matter were apparent from an early stage, compare to the first year. In the later stages of growth the difference in root biomass was high between the plants from the plots which received 80 kg N ha^{-1} in both years and the plants from zero plots in both years (Figure 4).

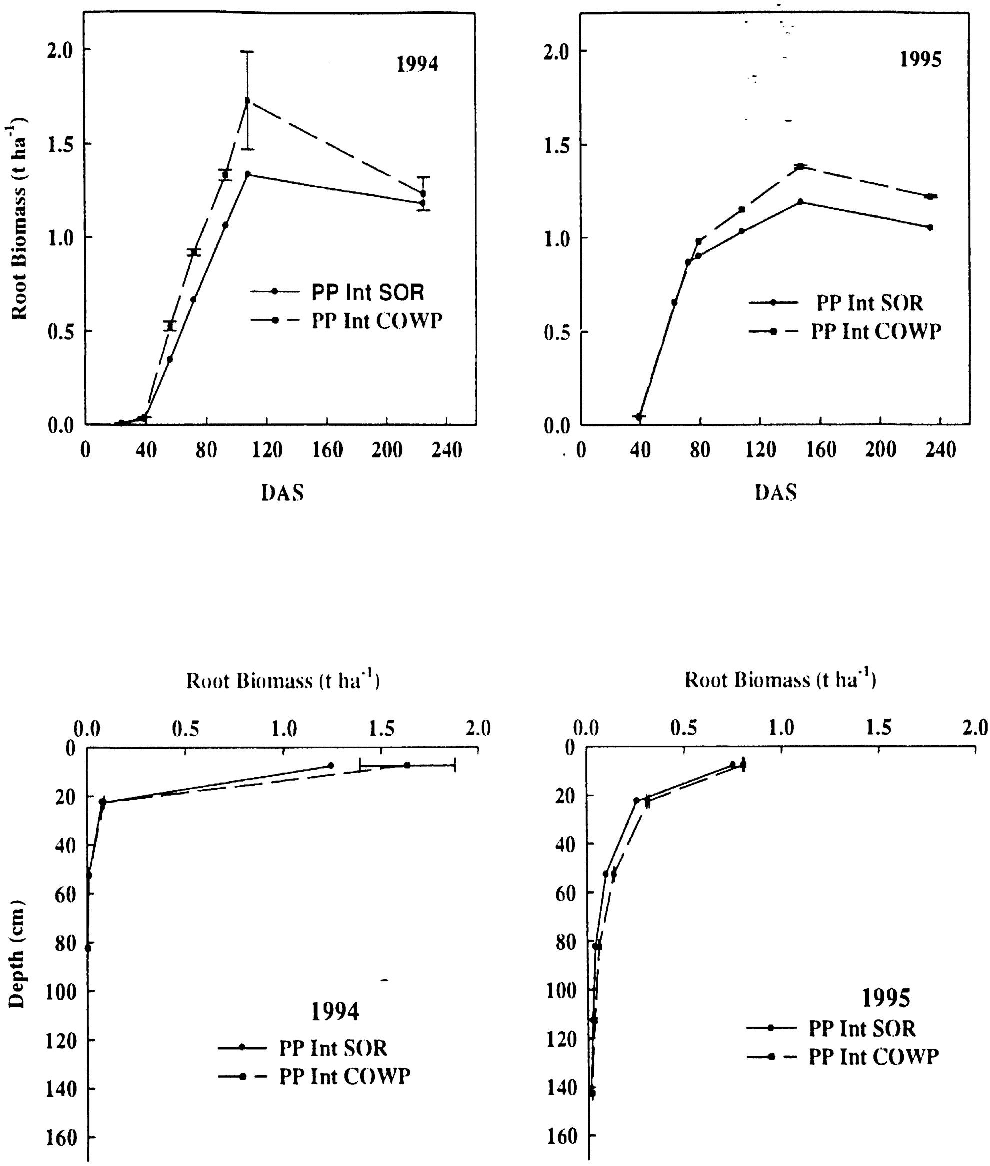

Figure 3 Root biomass of pigeonpea in S/PP and COW/PP intercropping and their root biomass distribution in the soil profile at maximum root biomass (108 DAS and 147 DAS in 1994 and 1995, respectively).

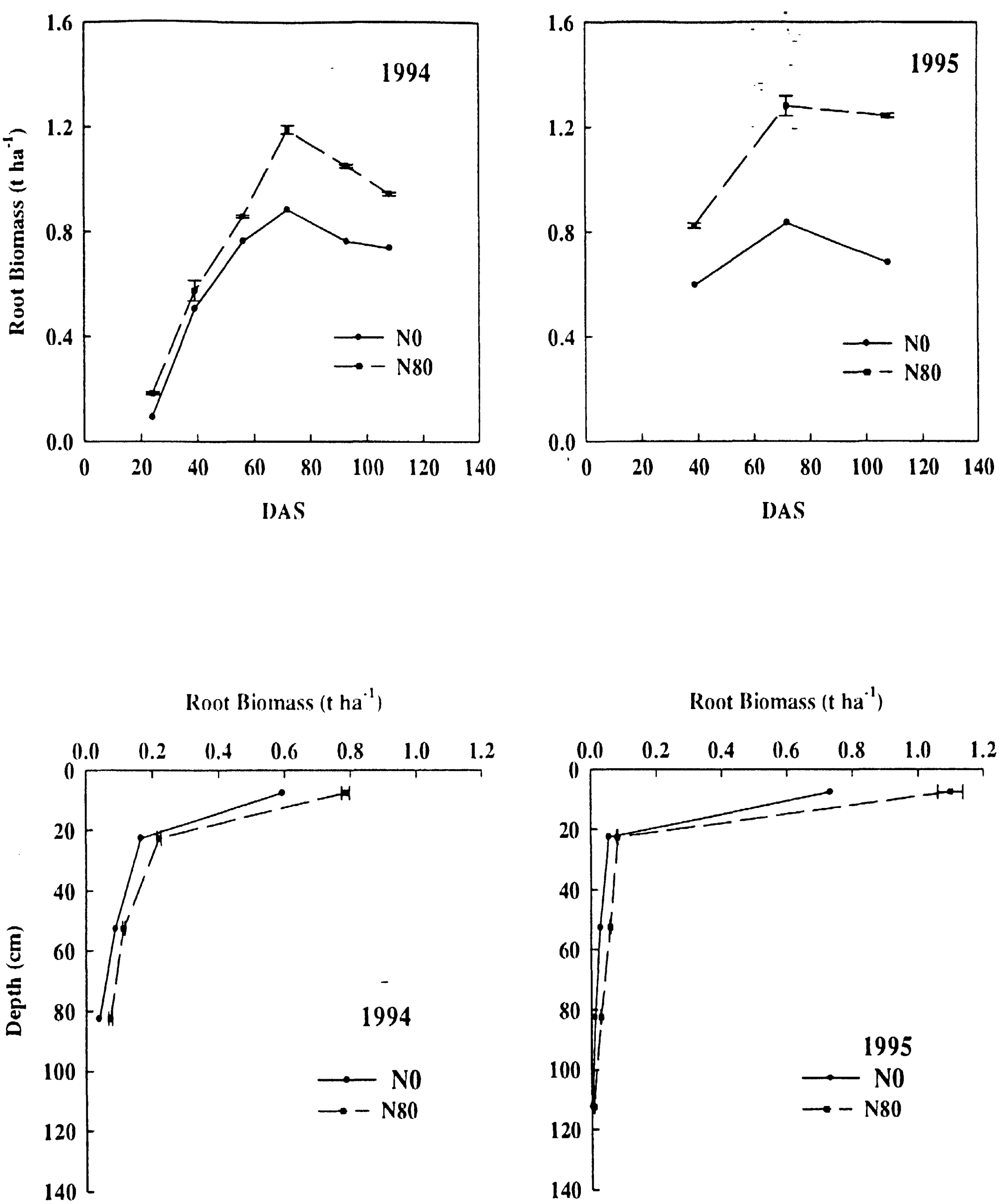

Figure 4 Root biomass of sole rainy season sorghum and its root biomass distribution in the soil profile at maximum root biomass.

Safflower crop is a component of this system (S+SAF S+SAF) and it was sown in the post-rainy season. In both years root growth of the crop continued till shortly before maturity, even though the rate of growth was less compared to the early stages. Differences in root dry matter between N80 and N0 plants were significant in both years. However, in 1994 safflower root dry matter was slightly lower compared to 1995 (Figure 5). In both years, the highest safflower root biomass was recorded at 130 DAS.

COW/PP S+SAF is a mixed legume and nonlegume system. In the first year cowpea and pigeonpea intercrops were grown and in the second year sorghum and safflower sequential crops were grown. Cowpea roots showed early growth and their biomass increased till maturity even though the rate of growth was slow in later growth stages (Figure 6). After the harvest of cowpea, pigeonpea root growth seemed to be activated, and the highest root dry matter was obtained at 108 DAS (Figure 3).

In the second year (1995) sorghum was grown in the rainy season and safflower in the postrainy season. The root biomass of rainy-season sorghum in fertilized plots was significantly higher than the root biomass in the non-fertilized plots. The highest root dry matter of sorghum was obtained at 72 DAS and it was 835 and 1282 kg ha^{-1} for N0 and N80 plots, respectively (Figure 4). Safflower followed the rainy-season sorghum and

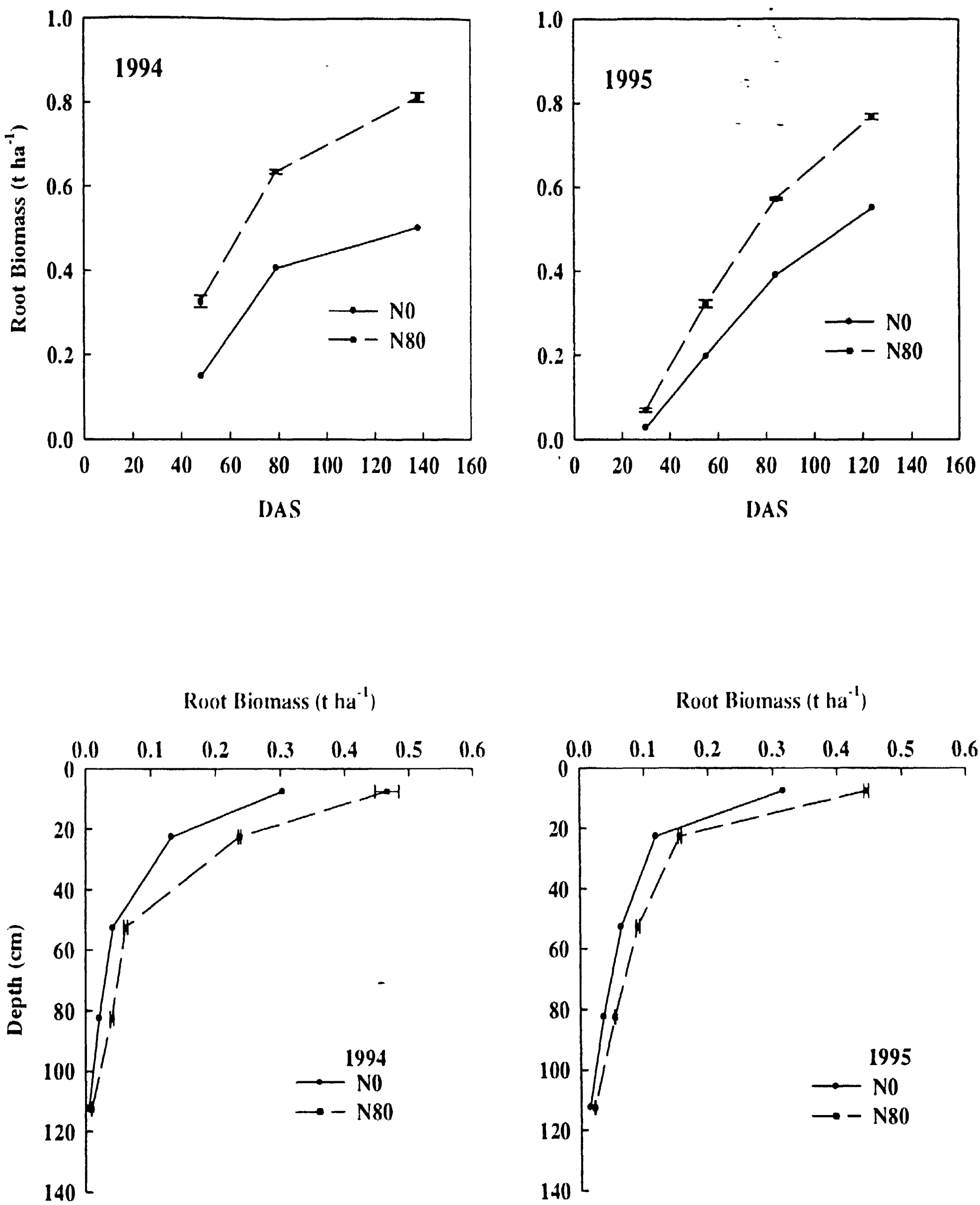

Figure 5 Root biomass of safflower and its root biomass distribution in the soil profile at maximum root biomass.

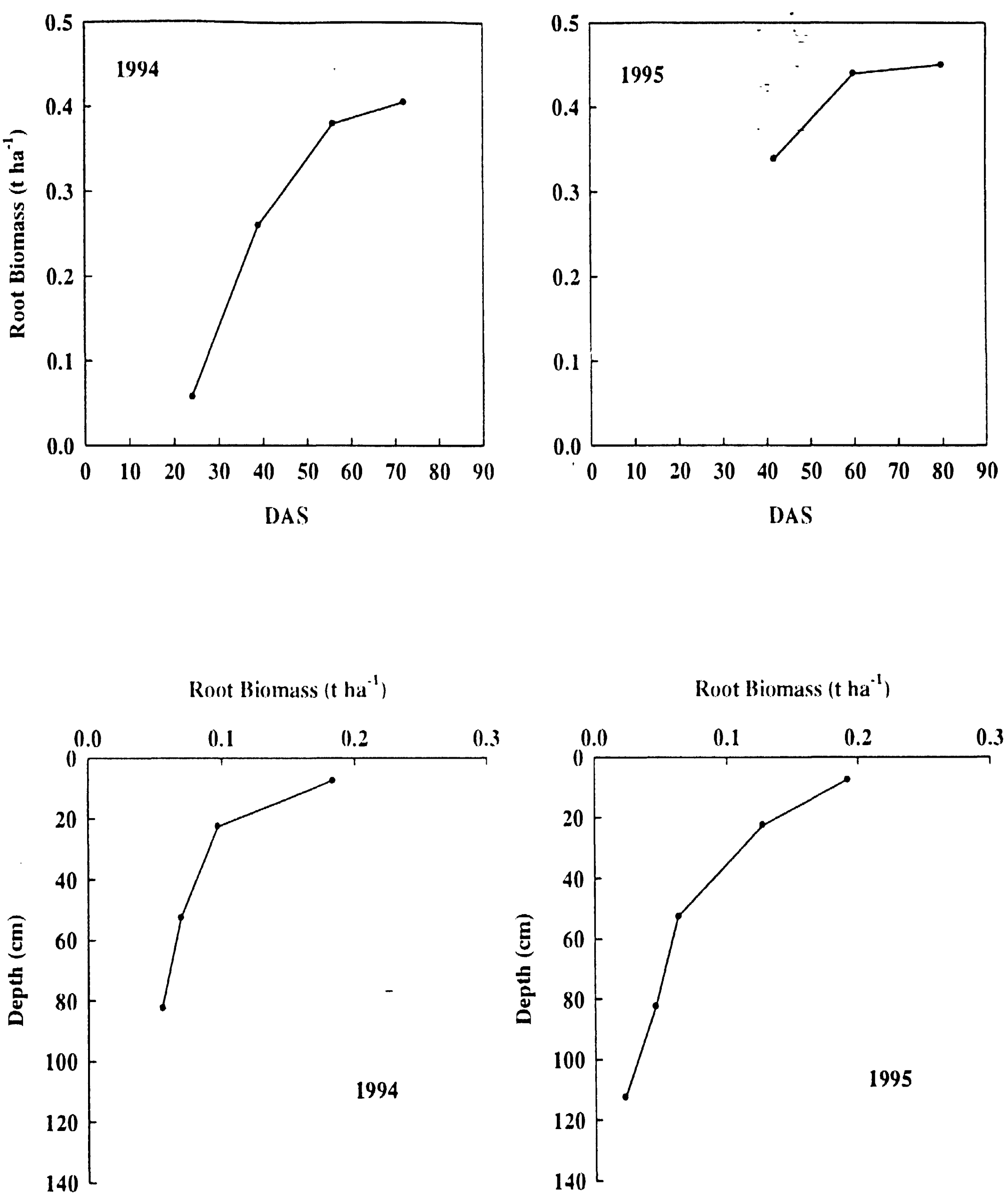

Figure 6 Root biomass of cowpea and its root biomass distribution in the soil profile at maximum root biomass.

it has been found that safflower root growth starts slowly in the initial stages, but its growth continues till physiological maturity. Maximum root biomass was found at 124 DAS and it was 550 kg ha^{-1} for N0 and 768 kg ha^{-1} for N80 plots (Figure 5)

In the S+SAF COW/PP system, sorghum was grown in the rainy season and safflower in the postrainy season of the first year. Sorghum data is shown in Figure 4. Safflower received fertilizer N and the crop which received 80 kg N ha^{-1} had significantly higher root dry matter than the zero N crop (Figure 5).

Cowpea and pigeonpea intercrops were grown in the second year. Cowpea root growth precedes pigeonpea root growth. Cowpea root dry matter increased till shortly before maturity but the rate of increase was lower compared to earlier growth stages (Figure 6). After harvest of cowpea, pigeonpea root dry matter increased and the maximum root biomass was obtained around 147 DAS (1379 kg ha^{-1}) (Figure 3).

In the F+S F+CKP system, plots were left under fallow in the rainy-season and crops were grown during the postrainy season. In 1994 postrainy season sorghum was grown. There was a significant difference in root dry matter between N80 and N0 crops.

The highest root biomass of 1200 kg ha^{-1} and 800 kg ha^{-1} for N80 and N0 was observed during flowering around 80 DAS (Figure 7). In the second year postrainy season chickpea was grown. The crop did not receive any fertilizer. The highest root dry matter was obtained at 84 DAS and it was 689 kg ha^{-1}(Figure 8).

In F+CKP F+S system which is a mirror image of the F+S F+CKP, chickpea was grown in the postrainy season of the first year, and sorghum in the postrainy season of the second year. Chickpea root biomass was highest at around 80 DAS (537 kg ha^{-1}) but later declined (Figure 8). In the second year postrainy season sorghum roots showed gradual increase in biomass till physiological maturity (120 DAS) (Figure 7)

Average root dry matter inputs of the different systems in each year are presented in Table 4. When no fertilizer was applied S/PP S/PP gave highest root dry matter with the system which involve fallows giving the lowest root dry matter, but when 80 kg N ha^{-1} was applied to the non-legume it is clear that even the non-legume can give higher amount of root dry matter.

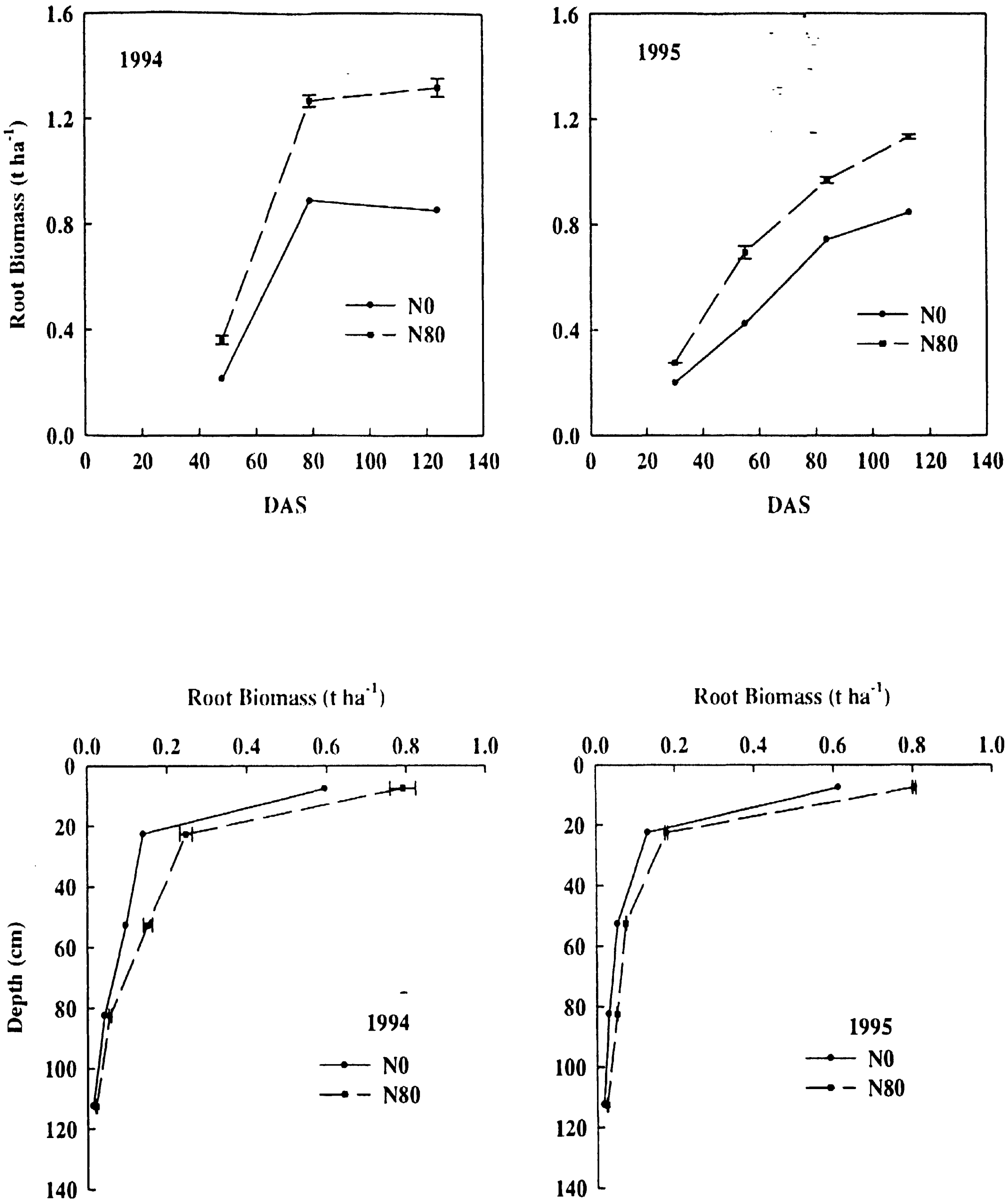

Figure 7 Root biomass of postrainy-season sorghum and its root biomass distribution in the soil profile at maximum root biomass.

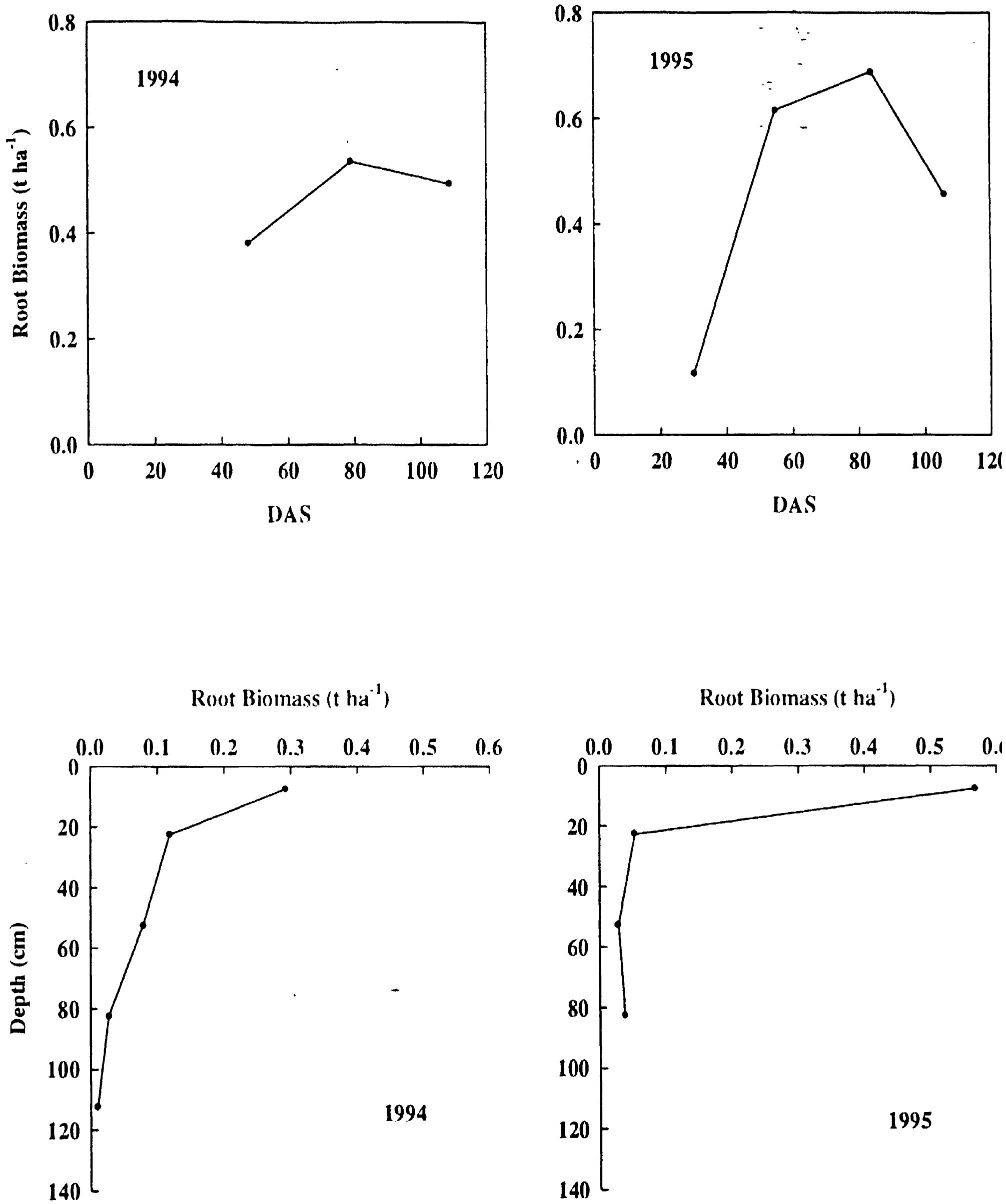

Figure 8 Root biomass of chickpea and its root biomass distribution in the soil profile at maximum root biomass.

Table 4 Average root dry matter inputs of different cropping systems rotations (kg ha^{-1})

System		N Levels (kg N ha^{-1})	
		N0	N80
S/PP S/PP		2395	2651
S+SAF S+SAF		1652	2210
[a]COW/PP S+SAF		1833	2112
[b]F+S F+CKP		818	943
SE(±) systems	80.4		
SE (±) N levels	46.4		

	I Year	II Year
S/PP S/PP	= Sorghum/Pigeonpea	Sorghum/Pigeonpea
S+SAF S+SAF	= Sorghum + Safflower	Sorghum + Safflower
COW/PP S+SAF	= Cowpea/Pigeonpea	Sorghum + Safflower
S+SAF COW/PP	= Sorghum + Safflower	Cowpea/Pigeonpea
F+S F+CKP	= Fallow + Sorghum	Fallow + Chickpea
F+CKP F+S	= Fallow + Chickpea	Fallow + Sorghum

[a]Average of COW/PP S+SAF and its mirror image system S+ SAF COW/PP.

[b]Average of F+S F+CKP and its mirror image system F+CKP F+S.

4.1.2. Pigeonpea and Cowpea Fallen leaves Organic Matter Inputs

Fallen leaf biomass was estimated in both years for pigeonpea and cowpea. Pigeonpea leaf fall started shortly before flowering and leaves were collected at weekly intervals. In 1994, at harvest time the fallen leaf biomass was 2500 kg ha^{-1}, whereas in 1995 only 1500 kg ha^{-1} fallen leaves were collected (Figure 9). Cowpea fallen leaves also contributed to the organic matter inputs to soil by way of fallen dry leaves. In 1994 the maximum amount of 136 kg ha^{-1} fallen leaves was collected shortly before the harvest of the crop (Figure 10). In 1995, leaves were collected and it has been found that around 146 kg ha^{-1} dry leaves were fallen during maturity of the crop (Figure 10).

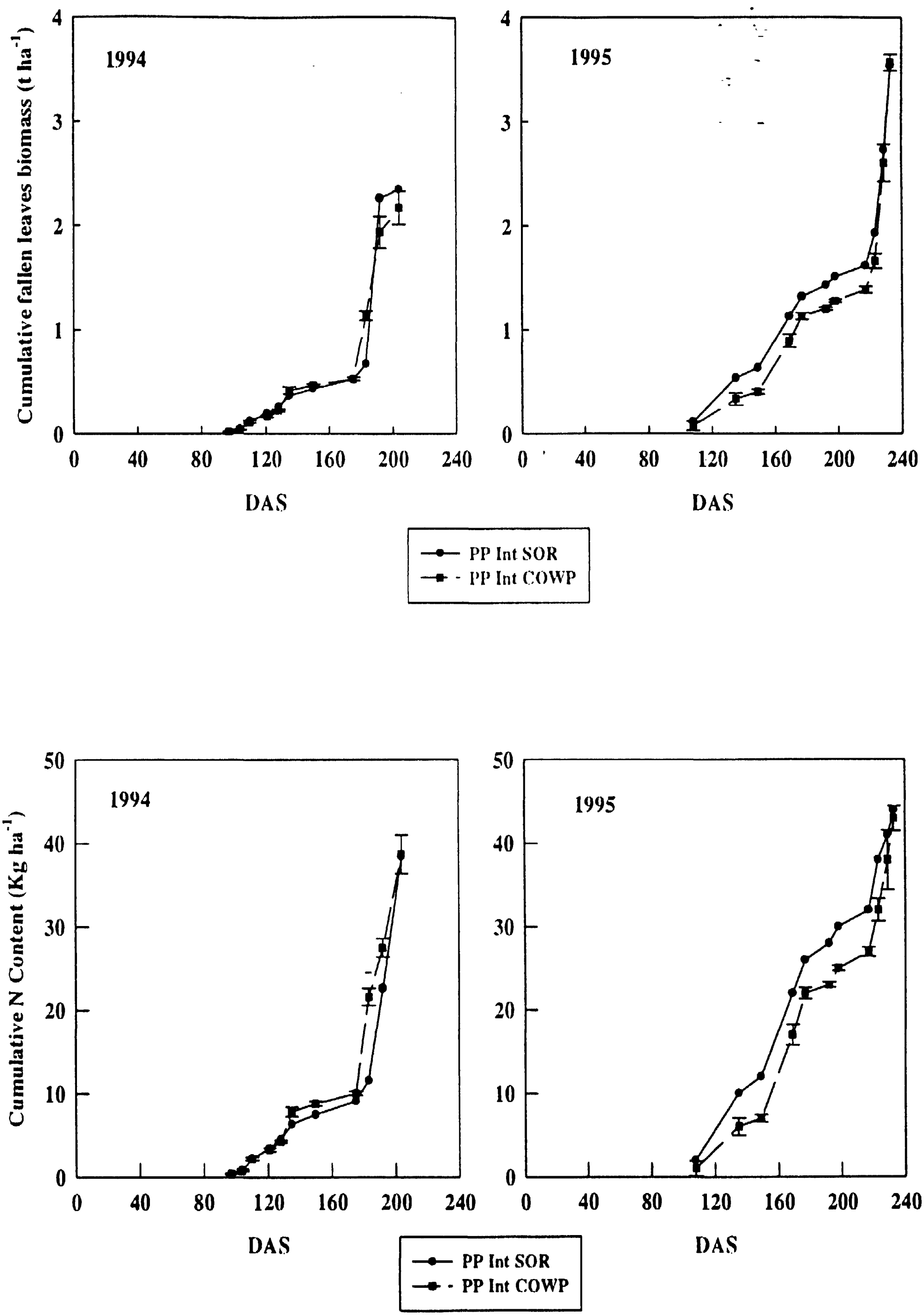

Figure 9 Cumulative biomass and N content of fallen leaves from pigeonpea intercropped with sorghum or cowpea.

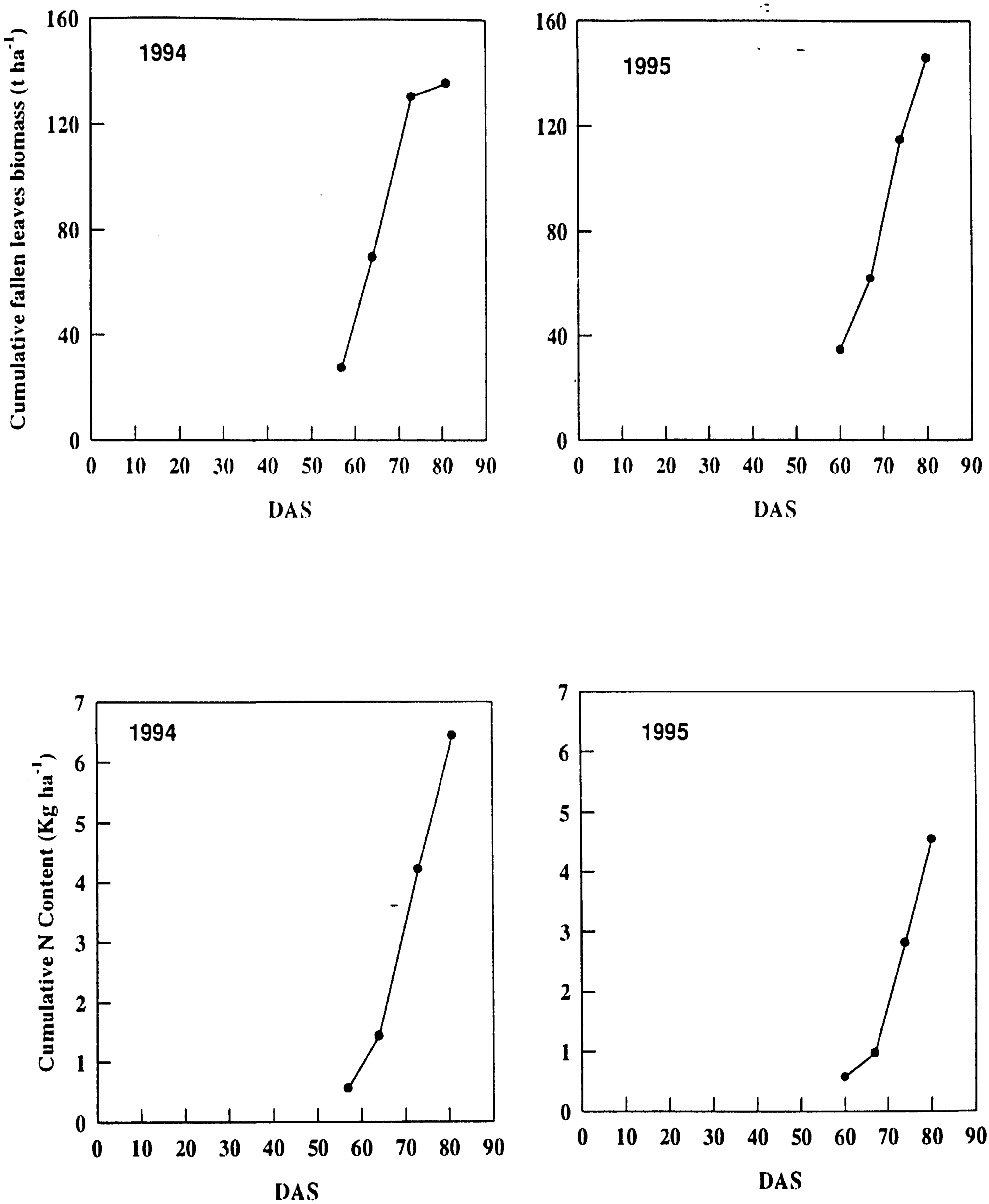

Figure 10 Cumulative biomass and N content of fallen leaves from cowpea intercropped with pigeonpea.

4.2. Nitrogen uptake patterns of the crops in the investigated cropping systems.

In the first year of the experiment, rainy season sorghum N uptake results show that sole sorghum with 80 kg N ha^{-1} had the highest N uptake (Figure 11) followed by intercrop sorghum with the same amount of N, and by sole sorghum with zero N. Intercropped sorghum with zero N had the lowest N uptake. In the initial stages of growth, N uptake of all sorghum crops (sole and intercrop) did not show any significant difference, but in the later stages of growth (from 60 DAS) there were significant differences in their N uptake (Figure 11).

In 1995, kharif sorghum dry weight and N uptake were affected by the preceding cropping systems and N level interactions. There was a significant difference between the treatments in N uptake. Sorghum preceded by COW/PP which received 80 kg N ha^{-1} had the highest N uptake, followed by sorghum preceded by S+SAF with 80 kg N ha^{-1}, and sorghum preceded by COW/PP with zero kg N ha^{-1} and the lowest N uptake was obtained from sorghum preceded by S+SAF with zero kg N ha^{-1} (Figure 11). In 1994 sole sorghum with zero N kg ha^{-1} had a higher N uptake than the same treatment in 1995. In 1994, intercropped sorghum with zero kg N ha^{-1} had a lower N uptake than the same crop in 1995. In general, all the 1995 rainy-season sorghum which received 80 kg N ha^{-1} showed higher N uptake than 1994 sorghum.

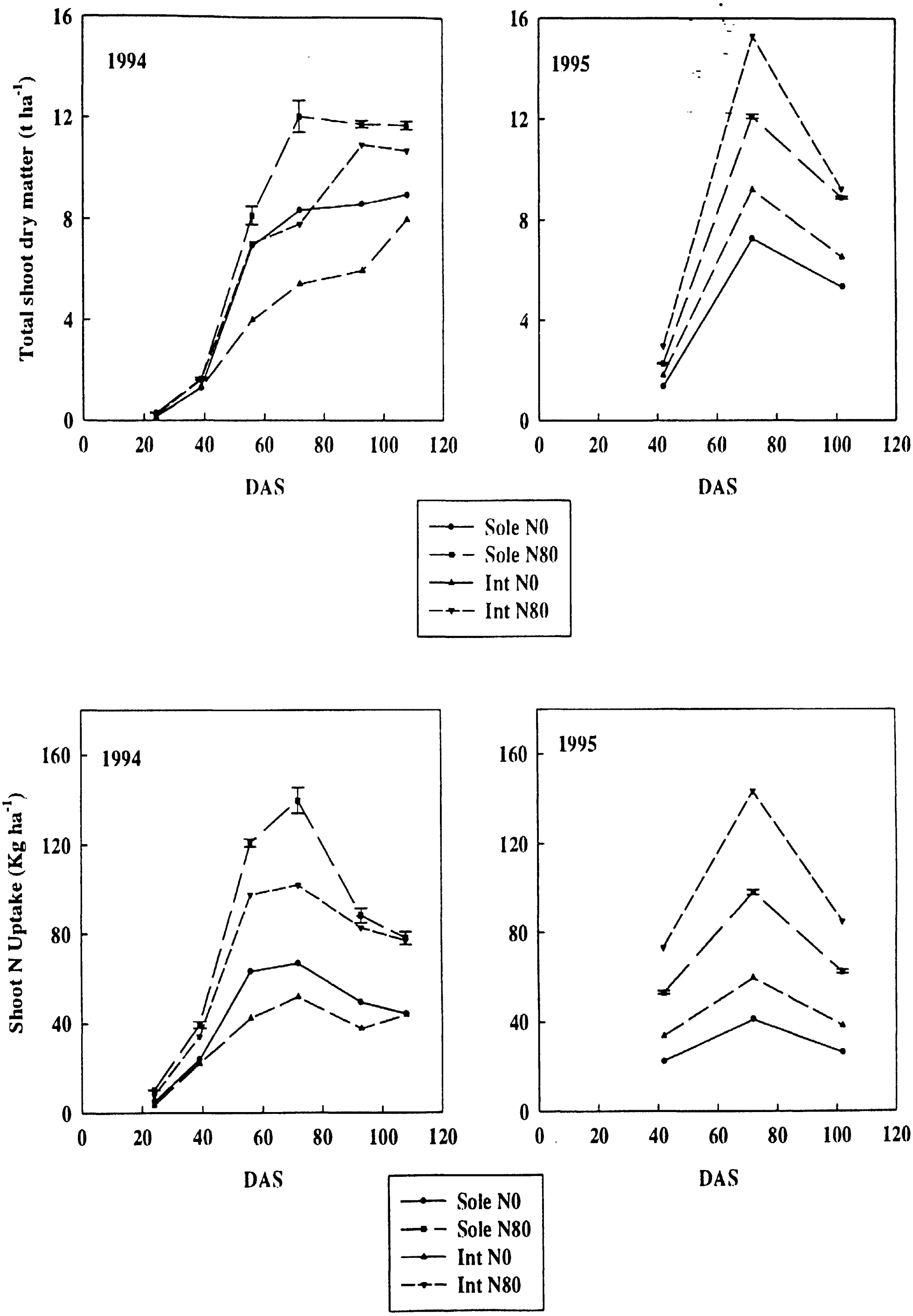

Figure 11 Total shoot dry matter and N uptake of rainy-season sorghum.

Pigeonpea was intercropped with sorghum and with cowpea. In 1994 it has been found that in the initial stages of the growth both pigeonpea crops did not show any significant difference in terms of N uptake, but in the later stages pigeonpea intercropped with cowpea had significantly higher N uptake than pigeonpea intercropped with sorghum (Figure 12).

In 1995, N uptake of both intercropped pigeonpea crops was not significantly different till 102 DAS, after that pigeonpea intercropped with cowpea showed significantly higher N uptake than the pigeonpea intercropped with sorghum (Figure 12). In general, in 1994 pigeonpea had slightly higher N uptake than in 1995.

Cowpea was intercropped with pigeonpea. In 1994 the crop N uptake rate was high in the initial stages where there was active vegetative growth, but it slowed after 55 DAS (Figure 13). The N uptake in 1994 peaked at 72 DAS when it was 68 kg N ha^{-1}, whereas in 1995, it peaked at 60 DAS (124 kg N ha^{-1}) but then decreased (Figure 13). Even though by 42 DAS both crops had almost similar N uptake rate, but at the peak of N uptake, 1995 crop seem to have taken up more N than the 1994 crop.

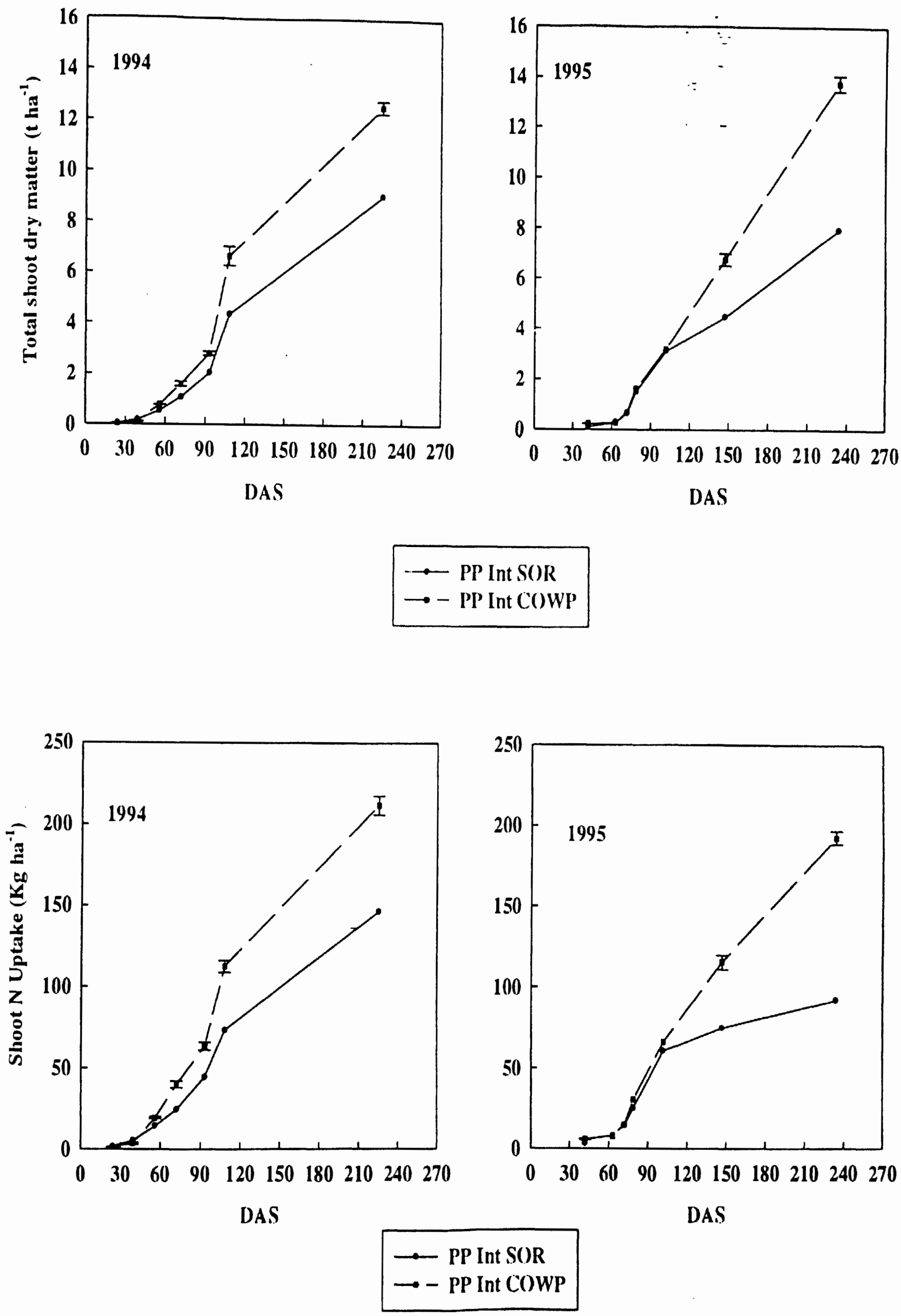

Figure 12 Total shoot dry matter and N uptake of pigeonpea.

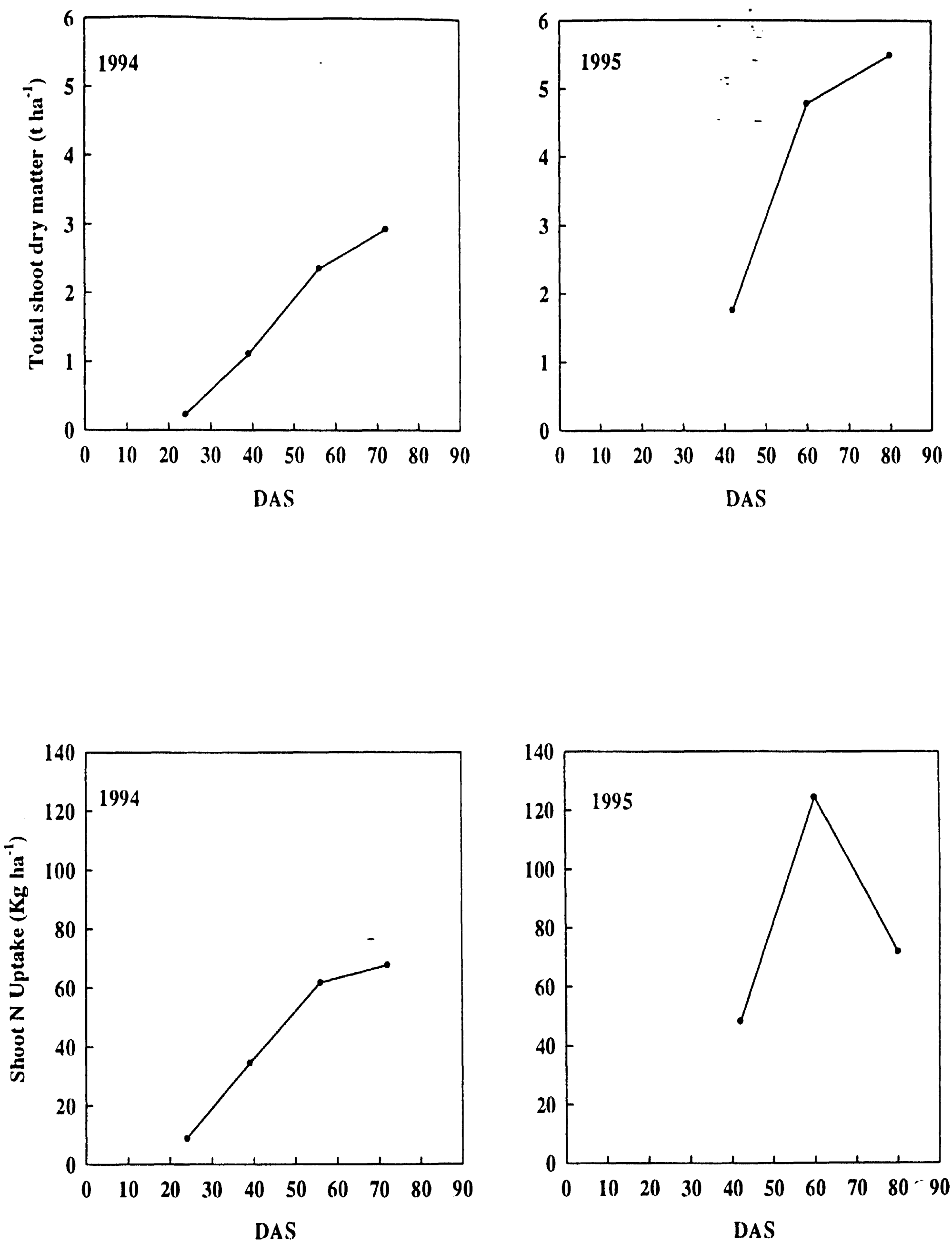

Figure 13 Total shoot dry matter and N uptake of cowpea.

Both sorghum and cowpea had higher N uptake than the pigeonpea till their harvest, and pigeonpea took up considerable N after the harvest of the associated crops. Pigeonpea intercropped with cowpea had significantly higher N uptake than the pigeonpea intercropped with sorghum (Figure 12).

Rabi (postrainy-season) sorghum was sown after a rainy season fallow. An N response in growth occurred and N uptake with 80 kg N ha^{-1} applied was significantly higher than the non-fertilized crop. Maximum N uptake was recorded at 80 DAS and was 44 and 67 kg N ha^{-1} for N0 and N80 crops respectively (Figure 14). In 1995 rabi sorghum receiving 80 kg N ha^{-1} had again a higher N uptake than the crop which received no fertilizer. Growth in N0 plots was far less than in N80 plots. Maximum N uptake was observed at 113 DAS and it was 30 kg N ha^{-1} for N0 plots and 60 kg N ha^{-1} for N80 plots. In general rabi sorghum had a higher N uptake in 1994 than 1995 crop when no fertilizer N was applied, but when adequate N fertilizer was given rabi sorghum in 1994 had a higher N uptake than 1995.

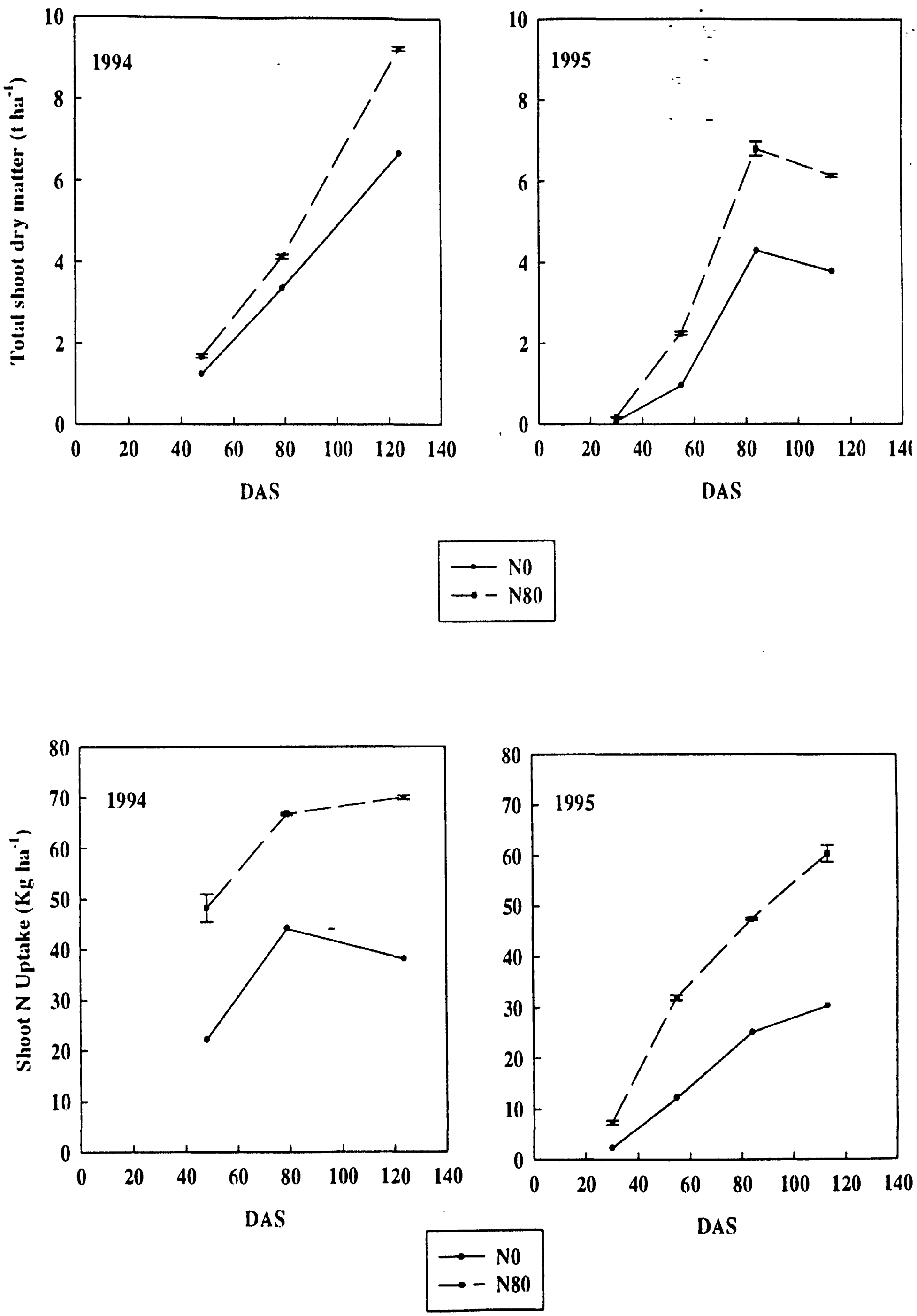

Figure 14 Total shoot dry matter and N uptake of postrainy-season sorghum.

Chickpea also was not preceded by a crop in 1994, and it was sown in fallow plots. Chickpea N uptake increased gradually till physiological maturity. In the second year chickpea was sown in plots where sorghum was grown in the 1994 postrainy season, but these plots were fallow in 1995 kharif. Nitrogen uptake of chickpea in 1995 was slightly greater compared to the first year. In 1995 the crop N uptake reached its peak at 84 DAS (83 kg N ha^{-1}) (Figure 15).

In 1994, Safflower was sown as a sole crop in the plots where sorghum was sown in the kharif season. N uptake of safflower with 80 kg N ha^{-1} was significantly higher than the non-fertilized crop (Figure 16). Highest N uptake was recorded at 80 DAS which was 38 and 68 kg N ha^{-1} for N0 and N80 respectively. In 1995, Safflower which received no fertilizer had lower N uptake, than the crop with 80 kg N ha^{-1} (Figure 16). In general it has been found that in 1995, N80 had slightly lower N uptake than the same treatment in 1994, but the non-fertilized crop in 1995 still had a lower in N uptake.

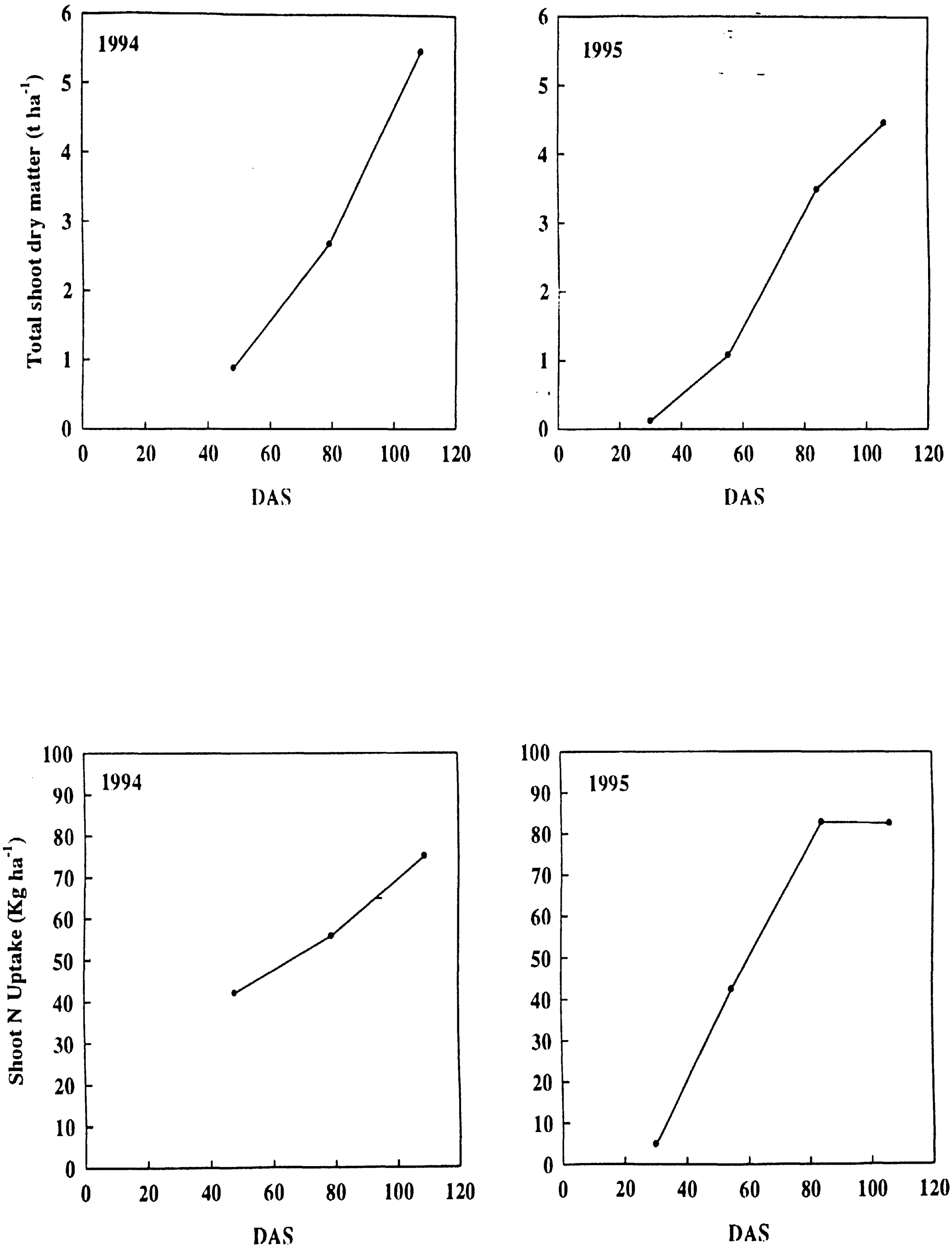

Figure 15 Total shoot dry matter and N uptake of chickpea.

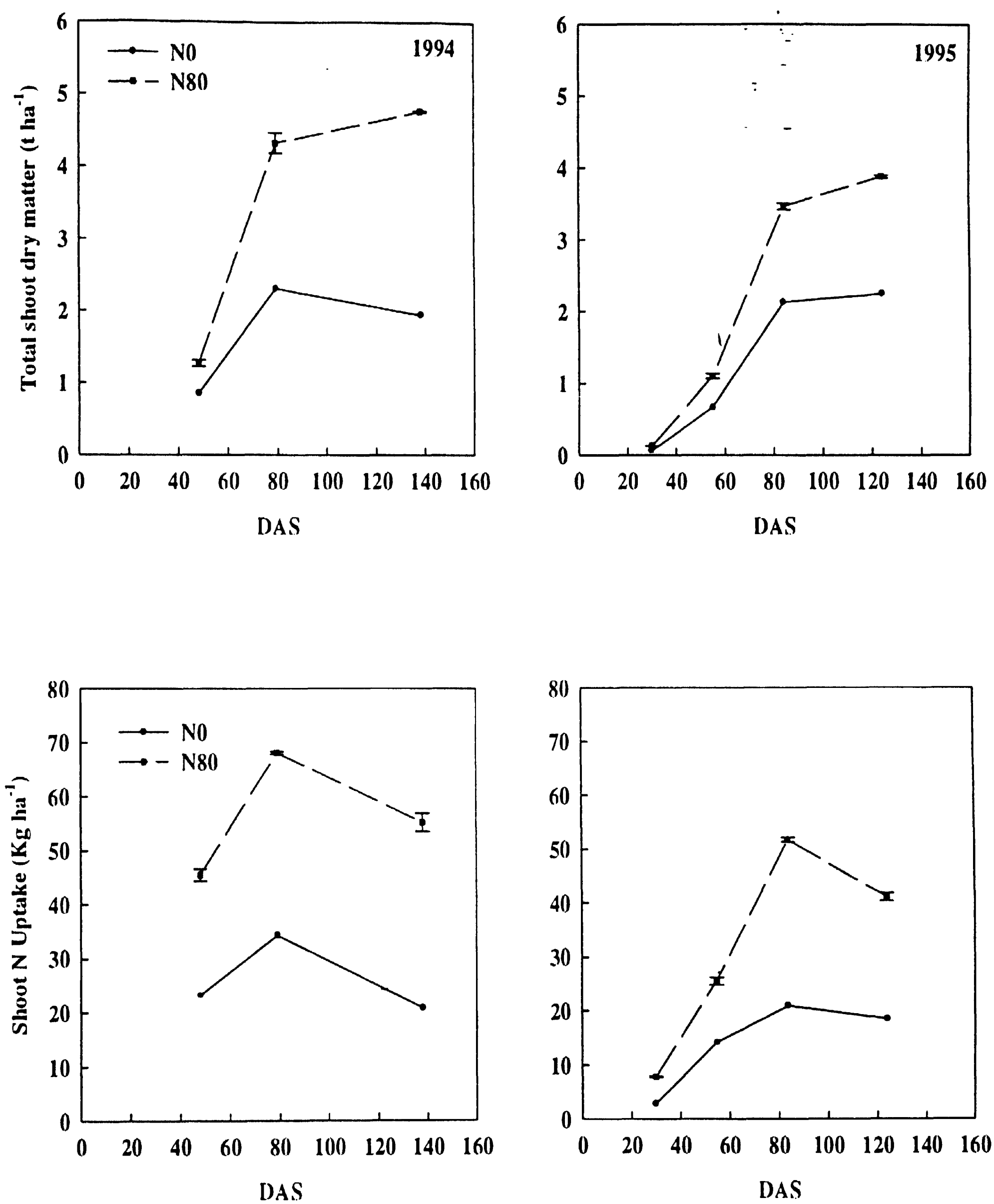

Figure 16 Total shoot dry matter and N uptake of safflower.

4.3. Quantification of nitrogen returns through leaf fall and roots

4.3.1. Nitrogen returns through roots of the different crops

Nitrogen content of rainy-season sorghum roots differs from one treatment to the other. In the first year of the experiment, the highest N returns through roots were obtained from sole sorghum with 80 kg N ha^{-1} followed by sorghum intercropped with pigeonpea which received 80 kg N ha^{-1} and the lowest was sorghum intercropped with pigeonpea without N application. The highest root N content was observed at 72 DAS (Figure 17). In 1995, rainy-season sorghum root N content was higher than 1994 at 42 DAS, and was much higher in at N80 than for N0 (Figure 17). In both years intercrop sorghum showed lower root N content than the sole crop sorghum.

In both years, pigeonpea was intercropped with sorghum and cowpea. In 1994, N returns through pigeonpea roots were almost similar in both intercrops (Figure 18). Nitrogen content of pigeonpea intercropped with sorghum and pigeonpea intercropped with cowpea was not significantly different. The maximum root N content of pigeonpea was recorded during the flowering stage (120 DAS). Pigeonpea in Cow/PP had 13 kg N ha^{-1} and in S/PP had 9.8 kg N ha^{-1}. Subsequently N content of roots decreased gradually (Figure 18). In 1995 pigeonpea root N content was slightly lower than in 1994.

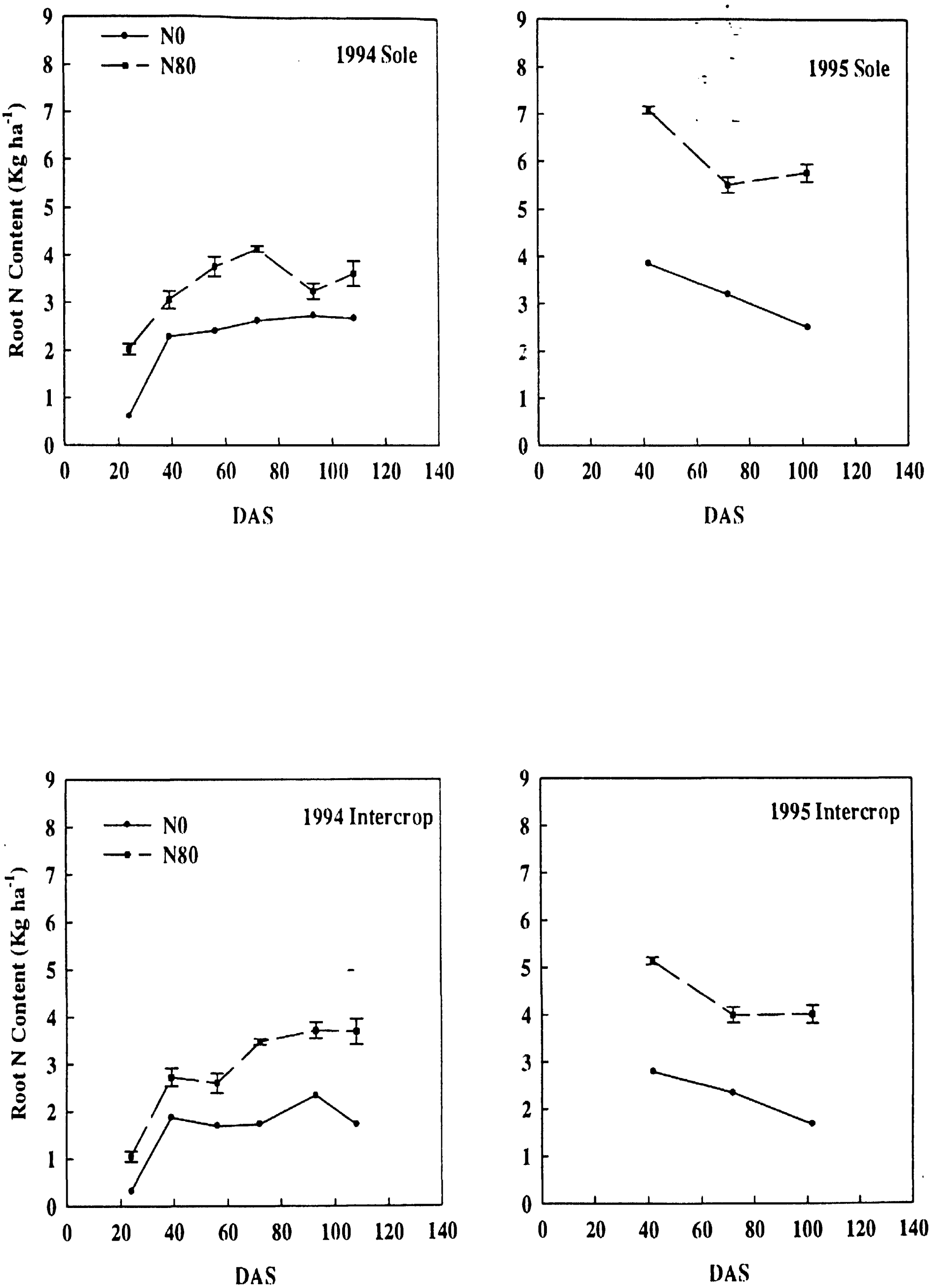

Figure 17 Root N content of rainy-season sorghum in 1994 and 1995.

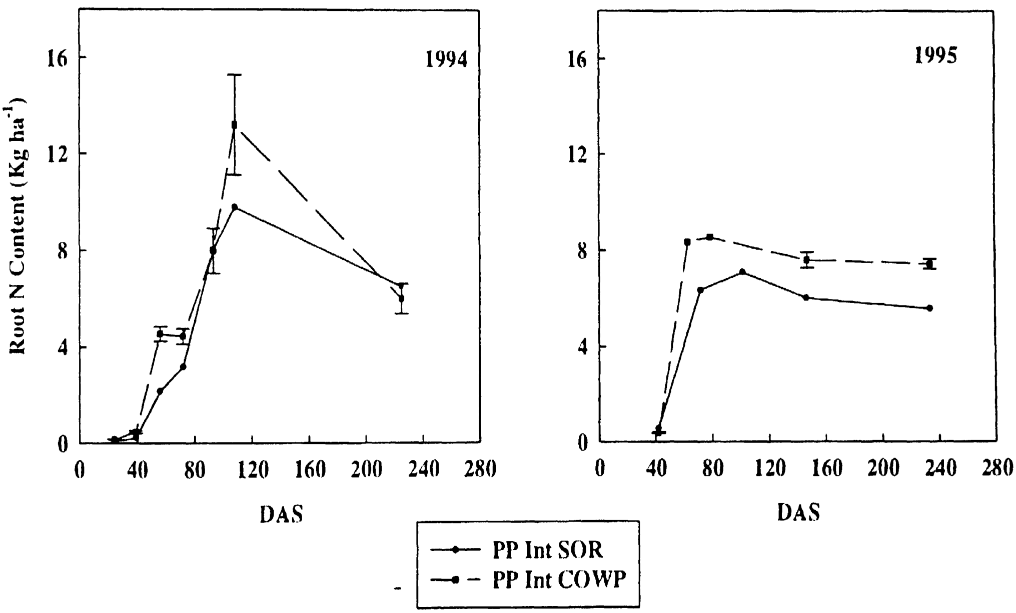

Figure 18 Pigeonpea root N content in 1994 and 1995.

The highest root N content was observed around 100 DAS and it was 9 kg N ha^{-1} for the pigeonpea intercropped with cowpea and 7 kg N ha^{-1} for the pigeonpea intercropped with sorghum.

Cowpea did not contribute much in terms of N through roots compared to pigeonpea. In 1994 highest N content of cowpea roots was observed at 50 DAS (3.4 kg N ha^{-1}), but in the later stages of growth the root N content seem to decline (Figure 19). Cowpea root N content was greater in the second year. The highest root N content was observed at 60 DAS (6.8 kg N ha^{-1}) subsequently it declined (Figure 19).

Nitrogen returns through roots of postrainy season sorghum in both years was low at the initial stages. In 1994 the maximum root N content was recorded at 80 DAS and was 2.6 kg N ha^{-1} and 4.3 kg N ha^{-1} in N0 and N80, respectively. In general, N uptake of roots increased till flowering and declined after that (Figure 20). In 1995, root N content of rabi sorghum was again significantly different between the fertilized treatment and non-fertilized treatments, N80 treatments showed higher root N returns than N0 treatments. In later stages, 1995 rabi sorghum had higher root N content compare to 1994 rabi sorghum, particularly N80 treatments (Figure 20).

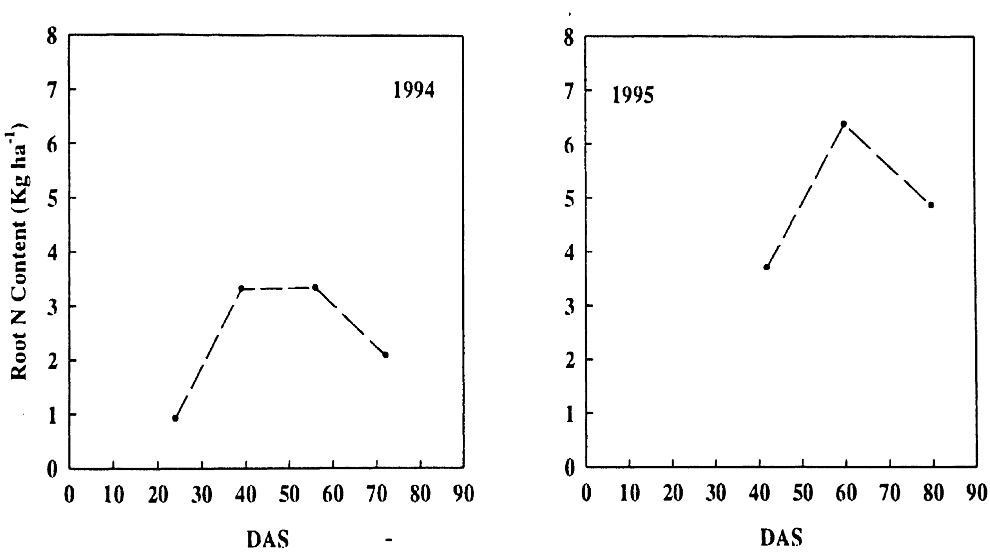

Figure 19 Cowpea root N content in 1994 and 1995.

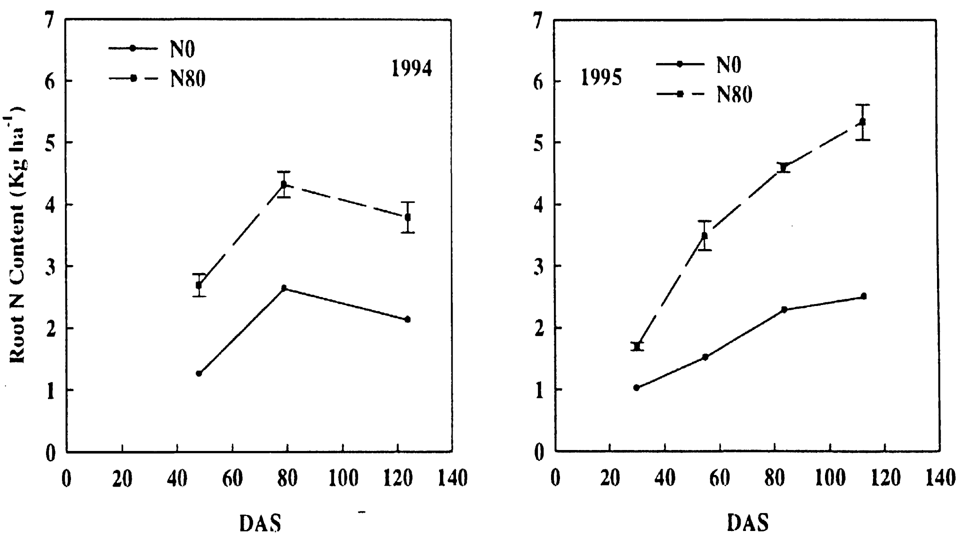

Figure 20 Root N content of postrainy-season sorghum in 1994 and 1995.

Root N content of 1994 chickpea was high initially (4.5 kg N ha^{-1}) and declined gradually till physiological maturity of the crop (Figure 21). Chickpea root N content increased in the second year compared to the first year. The highest root N content was observed at 55 DAS (8.6 kg N ha^{-1})(Figure 21).

Nitrogen returns through safflower roots were amongst the lowest of all crops. When adequately fertilized (80 kg N ha^{-1}), maximum root N content was 3.4 kg N ha^{-1} in 1994, but in case of N0, N returns through roots were around 1.7 kg N ha^{-1}(Figure 22). In 1995, root N content of safflower was higher than in 1994, and even though root N uptake started slowly it continued to increase. This increase was observed in the crop with 80 kg N ha^{-1}, but in N0 crop the root N content was almost similar to that of same treatment in 1994. Highest root N content was recorded at 120 DAS and it was 4.7 and 2.3 kg N ha^{-1} for N80 and N0, respectively.

Table 5 shows average N returns to the soil through roots of the crops in different systems. When no fertilizer N was applied the systems S/PP S/PP and COWP/PP S+SAF had root N return of around 14 kg N ha^{-1}, the lowest being F+S F+CKP (8 kg N ha^{-1}), but when fertilizer was applied the system S+SAF S+SAF gave almost the same amount of root N content, but the system F+S F+CKP had again low root N content compared to the other systems.

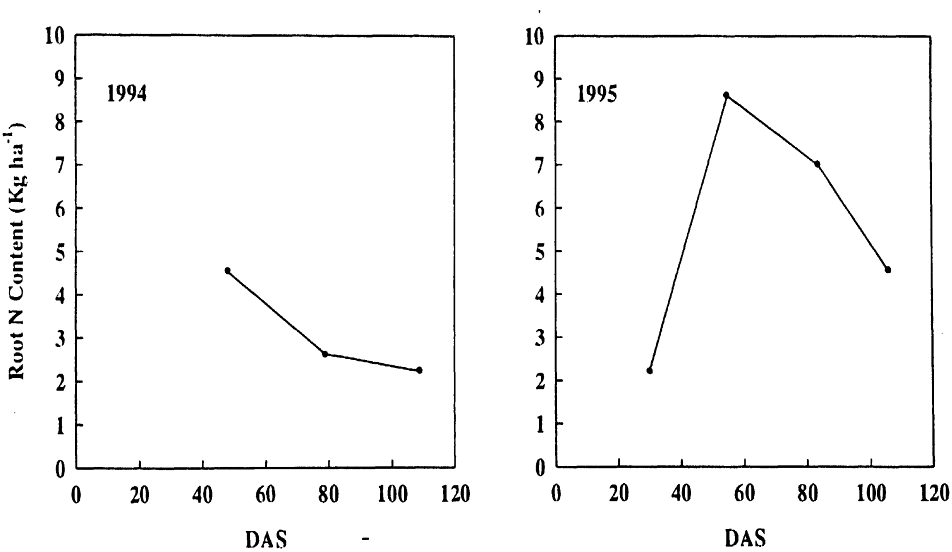

Figure 21 Chickpea root N content in 1994 and 1995.

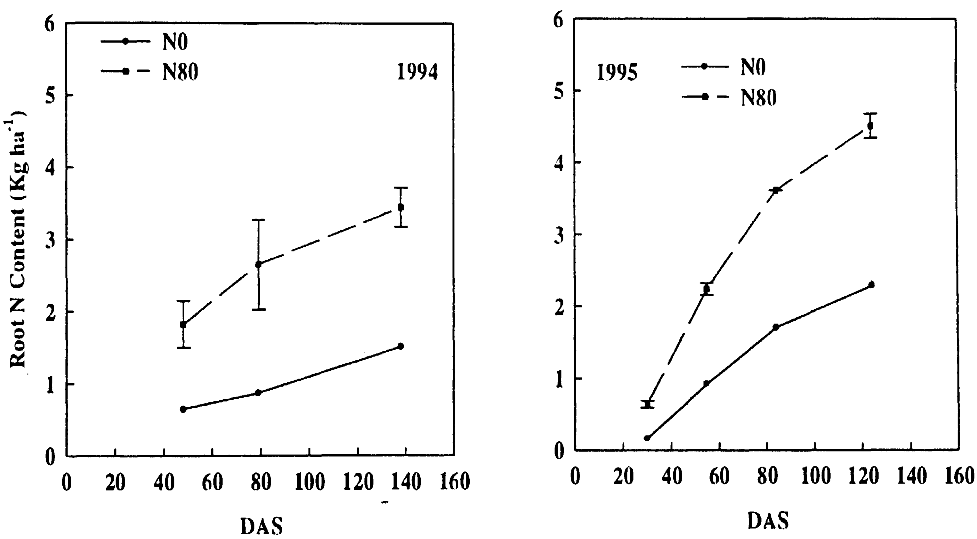

Figure 22 Safflower root N content in 1994 and 1995.

Table 5 Average root N inputs (kg N ha^{-1}) of different cropping systems rotations.

System		N Levels (kg N ha^{-1})	
		N0	N80
S/PP S/PP		14	17
S+SAF S+SAF		8	13
[a]COW/PP S+SAF		14	16
[b]F+S F+CKP		8	9
SE (±) systems	0.94		
SE (±) N levels	0.55		

	I Year	II Year
S/PP S/PP	= Sorghum/Pigeonpea	Sorghum/Pigeonpea
S+SAF S+SAF	= Sorghum + Safflower	Sorghum + Safflower
COW/PP S+SAF	= Cowpea/Pigeonpea	Sorghum + Safflower
S+SAF COW/PP	= Sorghum + Safflower	Cowpea/Pigeonpea
F+S F+CKP	= Fallow + Sorghum	Fallow + Chickpea
F+CKP F+S	= Fallow + Chickpea	Fallow + Sorghum

[a]Average of COW/PP S+SAF and its mirror image system S+ SAF COW/PP.

[b]Average of F+S F+CKP and its mirror image system F+CKP F+S.

4.3.2. Nitrogen return through fallen leaves of pigeonpea and cowpea

Pigeonpea contributes to improvement of the soil nutritional status through leaf fall. In 1994, N content of fallen pigeonpea leaves was 40 kg N ha^{-1} (Figure 9). In 1995, N returns through leaf fall was less than the first year of the experiment, and it was around 30 kg N ha^{-1} (Figure 9). In both years leaf fall started shortly before flowering, but the maximum leaf fall takes place during pod setting till harvest of the crop.

Cowpea also contributed N to the soil through leaf fall. The fallen leaves of cowpea contributed around 7 kg N ha^{-1} in 1994 (Figure 10). In 1995 N returns to the soil through leaf fall were similar to the first year. Nitrogen content in fallen leaves increased gradually till 80 DAS or almost shortly before harvest. Nitrogen content of fallen leaves at that stage was around 2.3 kg N ha^{-1} (Figure 10). Cowpea does not contribute much of N through leaf fall compared to pigeonpea which has a bigger crop canopy and also longer duration.

4.4. Nitrogen contribution from legumes to the following non-leguminous crops.

4.4.1. 1995 rainy-season Sorghum:

This was studied in the second year of the experiment. The response of rainy-season sorghum to N showed the different residual effects of the cropping system in the previous year and the proportion of legumes in the previous year. Sorghum gave good yield (4000 kg ha^{-1}) when given adequate doses of N fertilizer. In the absence of N fertilizer, grain yields of sorghum were 2780 kg ha^{-1} after double legume intercrop (Cowpea/PPea), and 1950 kg ha^{-1} after a double non-legume sequential crop (Sorghum+Safflower). The legume non-legume intercrop combination (Sorghum/PPea Sorghum/PPea) gave grain yield of 2500 kg ha^{-1} (Figure 23) (Plate 9, 10 and 11). These results show that inclusion of legumes in double-cropping system gave a residual effect of equivalent of 35-38 kg of fertilizer N ha^{-1} and that N uptake by the sorghum increased by 20 kg N ha^{-1}.

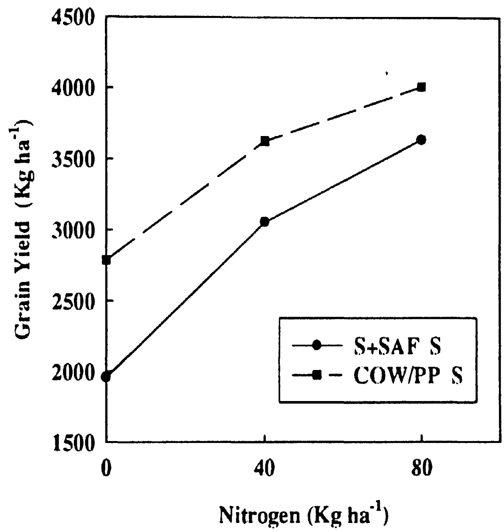

Figure 23 Effect of previous cropping system on response of rainy-season sorghum to fertilizer N.

Plate 9: 1995 kharif sorghum in the COWP/PP S + SAF system with N0. The plants in these plots were matching in growth with the plants in the fertilized plots of the S+SAF S+SAF system.

Plate 10: 1995 kharif sorghum in the S/PP S/PP system with N0.

Plate 11: 1995 kharif sorghum in the S+SAF S+SAF system with N0. Note the poor growth and late flowering of the plants compared to the sorghum plants in the COW/PP S+SAF system (plate 9) or in S/PP S/PP (plate 10).

4.4.2. 1995 Safflower :

Safflower treatments were COW/PP S+SAF and S+SAF S+SAF. The response of safflower to N did not reflect much about the residual effect of the legumes in the previous cropping system.

Grain yield of safflower increased with the increase in N fertilizer dose. Maximum grain yield was obtained from the of COW/PP S+SAF treatment with 80 kg N ha^{-1} (1210 kg ha^{-1}) followed by S+SAF S+SAF with 80 kg N ha^{-1} (Figure 24) (Plate 12 and 13). In case of N0, safflower in the COW/PP S+SAF treatment gave a grain yield of 590 kg ha^{-1} and in the S+SAF S+SAF treatment gave a grain yield of 470 kg ha^{-1}. Inclusion of legumes in the cropping systems gave a residual effect equivalent to 10-15 kg N ha^{-1}, and the N uptake by safflower increased by 6 kg N ha^{-1}.

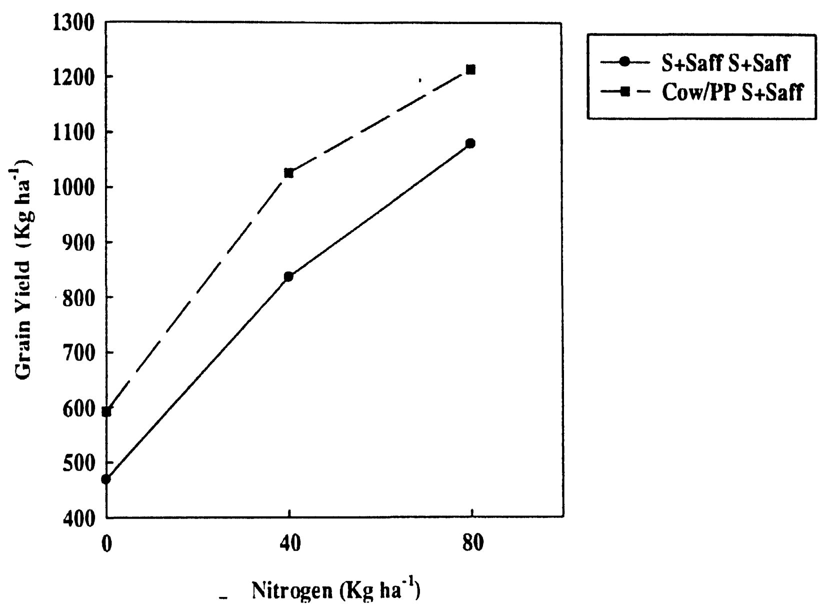

Figure 24 Effect of previous cropping system on response of safflower to fertilizer N.

Plate 12: 1995 safflower in the COW/PP S+SAF system with N0.

Plate 13: 1995 safflower in the S+SAF S+SAF system with N0. Note the poor growth of the crop compared to the safflower crop after COW/PP (Plate 12)

4.5. Amount of N_2 fixed by the legume crops

Table 6,7,8 and 9 show the results of dry matter produced and total N uptake by pigeonpea, cowpea, chickpea and sorghum and estimates of N fixed by those crops in N0 plots. Sorghum was used as a reference crop. The three legume crops used in the experiment showed differences in N uptake and net nitrogen fixation. Pigeonpea fixed 148 kg N ha^{-1} followed by chickpea 32 kg N ha^{-1} and lowest was cowpea with 27 kg N ha^{-1}. Nitrogen harvest index (NHI) for pigeopea was 0.29, chickpea 0.7 and cowpea 0.33.

Table 6. Grain yield, dry matter production (kg ha^{-1}) and harvest index at maturity of all crops in 1994.

Crop	Grain yield	Pod wall/chaff	Shoot	Roots	Fallen Leaves	-Total dry matter	Harvest Index
Pigeonpea	1560	974	6490	1236	2348	12608	0.12
Cowpea	638	277	2016	406	131	3468	0.18
Chickpea	2276	197	2991	494	-	5959	0.38
Kharif sorghum	2715	492	5359	670	-	9236	0.29
Rabi sorghum	3130	563	3537	853	-	8083	0.38
Safflower	533	133	1450	503	-	2619	0.20

Table 7. N content (kg ha^{-1}) of different plant parts at maturity of all crops in 1994.

Crop	Grain	Pod wall	Shoot	Roots	Fallen Leaves	[a]Resid. N	Total N uptake	[b]Estim. N_2 fixed	Harvest Index for N (NHI)
Pigeonpea	56	14	76	6	40	53	193	148	0.30
Cowpea	24	5	39	2	3	7	72	27	0.33
Chickpea	54	1	20	2	-	5	77	32	0.70
Kh. sorghum	22	2	19	2	-	-	45	-	0.50
R.sorghum	27	2	9	2	-	-	40	-	0.67
Safflower	10	1	7	1	-	-	19	-	0.53

[a]Calculated as root N × 2[c] + N in fallen plant parts.

[b]N_2-fixation calculated as total N uptake of legume minus sorghum N uptake.

[c]It assumed that 50% of the roots can be recovered, therefore root N is multiplied by 2. (Sheldrake and Narayanan 1979; Kumar Rao and Dart 1987).

Table 8. Grain yield, dry matter production (kg ha^{-1}) and harvest index at maturity of all crops in 1995.

Crop	Grain yield	Pod wall	Shoot	Roots	Fallen Leaves	Total dry matter	Harvest Index
Pigeonpea	492	819	6494	1054	1506	10365	0.05
Cowpea	1367	348	2863	450	146	5174	0.26
Chickpea	2483	643	1337	457	-	4921	0.50
Kharif Sorghum	2228	382	3317	603	-	6530	0.34
Rabi sorghum	1215	285	2114	847	-	4461	0.27
Safflower	531	335	1331	551	-	2748	0.20

Table 9. N content (kg ha^{-1}) of the different plant parts at maturity of all crops in 1995.

Crop	Grain	Pod wall	Shoot	Roots	Fallen Leaves	[a]Resid. N	Total N uptake	[b]Estim. N_2 fixed	Harvest Index for N (NHI)
Pigeonpea	17	15	56	6	30	41	123	88	0.14
Cowpea	55	4	44	5	2	12	109	75	0.50
Chickpea	68	3	68	5	-	9	87	53	0.78
Kharif sorghum	20	1	11	2	-	-	35	-	0.58
Rabi sorghum	22	2	9	3	-	-	36	-	0.60
Safflower	9	1	5	2	-	-	17	-	0.53

[a]Calculated as root N × 2^c + N in fallen plant parts.

[b]N_2-fixation calculated as total N uptake of legume minus sorghum N uptake.

[c]It assumed that 50% of the roots can be recovered, therefore root N is multiplied by 2. (Sheldrake and Narayanan 1979; Kumar Rao and Dart 1987).

4.6. Nitrogen balance of legume systems

Table 10 shows net N balance for the legumes in both years of the experiment using N difference method (Peoples and Craswell 1992).

Table 10 shows that pigeonpea gave a positive balance of 92 kg N ha^{-1} in the first year and 71 kg N ha^{-1} in the second year, cowpea +3 and +20 kg N ha^{-1} in 1994 and 1995 respectively. Chickpea had a negative balance in both years which was -22 and -15 in 1994 and 1995, respectively.

The N balance was calculated as:

Net N balance = Nf - Nls

where Nf = (P × Nl)

and Nls = (NHI × Nl)

In this calculation inputs as seed were not included. Also leaching and gaseous losses were not considered in the calculation.

Table 10. Net N balance for the legumes grown in 1994 and 1995

Crop	[a]Seed yield kg N ha^{-1}	[b]Total crop N kg N ha^{-1}	[c]NHI	N_2 fixed		[e]Net N balance kg N ha^{-1}
				P	[d]Amount kg N ha^{-1} $Crop^{-1}$	
A. 1994						
Pigeonpea	56	193	0.29	0.77	148	+ 92
Cowpea	24	72	0.33	0.38	27	+ 30
[f]Chickpea	54	77	0.70	0.42	32	- 22
[g]Chickpea	54	77	0.70	0.48	37	- 17
[h]Chickpea	54	77	0.70	0.75	58	+ 4
B. 1995						
Pigeonpea	17	123	0.14	0.72	88	+ 71
Cowpea	55	109	0.50	0.69	75	+ 20
[f]Chickpea	68	87	0.78	0.61	53	- 15
[g]Chickpea	68	87	0.78	0.60	51	- 17
[h]Chickpea	68	87	0.78	0.80	70	+ 2

[a]N removed in seed, Nls.
[b]Total crop N at seed harvest, Nl.
[c]Nitrogen harvest index = Nls / Nl.
[d]Amount of N2 fixed, Nf = Nl × P.
[e]Net contribution of legume to soil = Nf - Nls.
[f]Reference crop is rainy-season sorghum
[g]Reference crop is postrainy-season sorghum
[h]Reference crop is safflower

4.7. Effect of cropping systems rotations on soil nutritional status

4.7.1. Total Nitrogen

There was no significant effect of cropping systems, N levels or their interaction on soil total N, (Figure 25) which is to be expected in view of the short term in which this investigation was carried out. The initial soil total N of the different soil layers is shown in Table 3. There was no significant increase in soil total N nor any significant difference between the treatments.

4.7.2. Soil pH

The soil pH also did not change significantly over the period of the experiment, (Table 11) Comparing the results obtained at the end of the experiment to the initial pH, it is clear that there was no effect of the rotations on the soil pH, and no significant difference between the treatments. However, pH might change in the longer term.

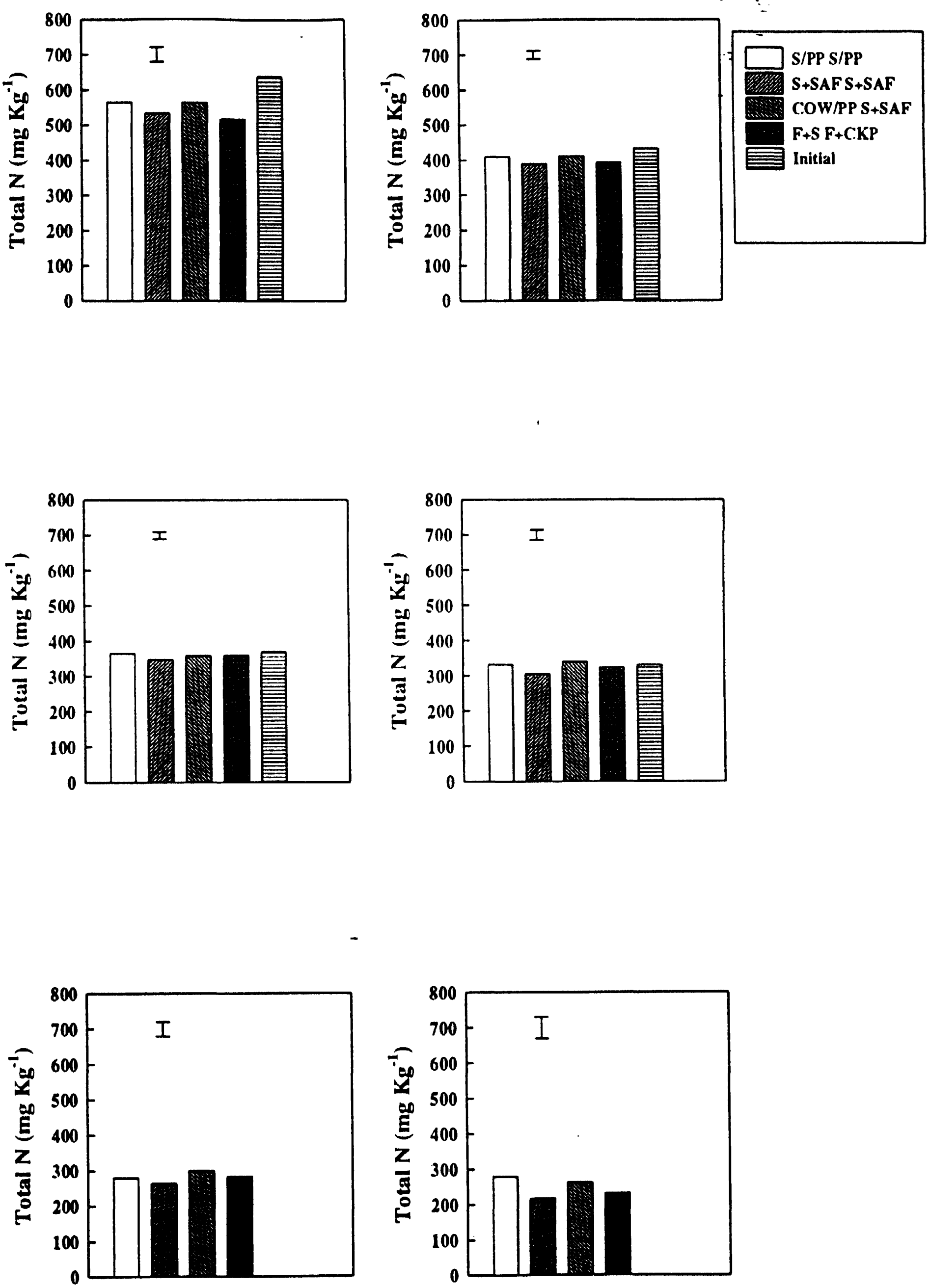

Figure 25 Effect of cropping systems rotations on total N content of the soil.

Table 11 Effect of cropping systems rotations on soil pH

	Depths (cm)					
Systems	0-15	15-30	30-60	60-90	90-120	120-150
Initial	8.19	8.33	8.40	8.32	NM	NM
S/PP S/PP	8.22	8.33	8.36	8.43	8.48	8.56
S+SAF S+SAF	8.18	8.30	8.30	8.33	8.39	8.44
COWP/PP S+SAF	8.16	8.31	8.31	8.33	8.41	8.47
S+SAF COWP/PP	8.16	8.27	8.29	8.33	8.43	8.50
F+S F+CKP	8.27	8.37	8.39	8.42	8.52	8.57
F+CKP F+S	8.22	8.39	8.38	8.37	8.39	8.47
SE ±	0.048	0.047	0.042	0.057	0.058	0.055

NM = Not Measured

4.7.3. Soil Electrical Conductivity (EC)

Table 12 show effect of the cropping systems rotations on soil EC. There was no significant difference between the treatments in the changes of the soil EC. Results show that the changes of soil EC with time were negligible.

Table 12 Effect of cropping systems rotations on soil EC (d S m^{-1})

	Depths (cm)					
Systems	0-15	15-30	30-60	60-90	90-120	120-150
Initial	0.26	0.17	0.16	0.23	NM	NM
S/PP S/PP	0.17	0.16	0.17	0.19	0.22	0.27
S+SAF S+SAF	0.21	0.17	0.17	0.19	0.21	0.24
COWP/PP S+SAF	0.20	0.16	0.17	0.18	0.21	0.24
S+SAF COWP/PP	0.22	0.19	0.19	0.21	0.27	0.28
F+S F+CKP	0.19	0.15	0.16	0.18	0.21	0.24
F+CKP F+S	0.19	0.15	0.16	0.17	0.24	0.23
SE ±	0.024	0.020	0.017	0.016	0.032	0.027

NM = Not Measured

4.7.4. Soil NO_3 -N

Cropping systems rotations and nitrogen applications had significant effect on soil NO_3 -N. The initial soil NO_3 -N was less than 1 ppm. A marked effect of interactions was found in the N0 treatments (Figure 26). The cropping system S/PP S/PP significantly increased the soil NO_3 -N, whereas S+SAF S+SAF decreased it. The systems with legumes in only one year showed also some improvement in soil NO_3 -N. The effect of the cropping systems rotations was found only in 0-60 cm depth.

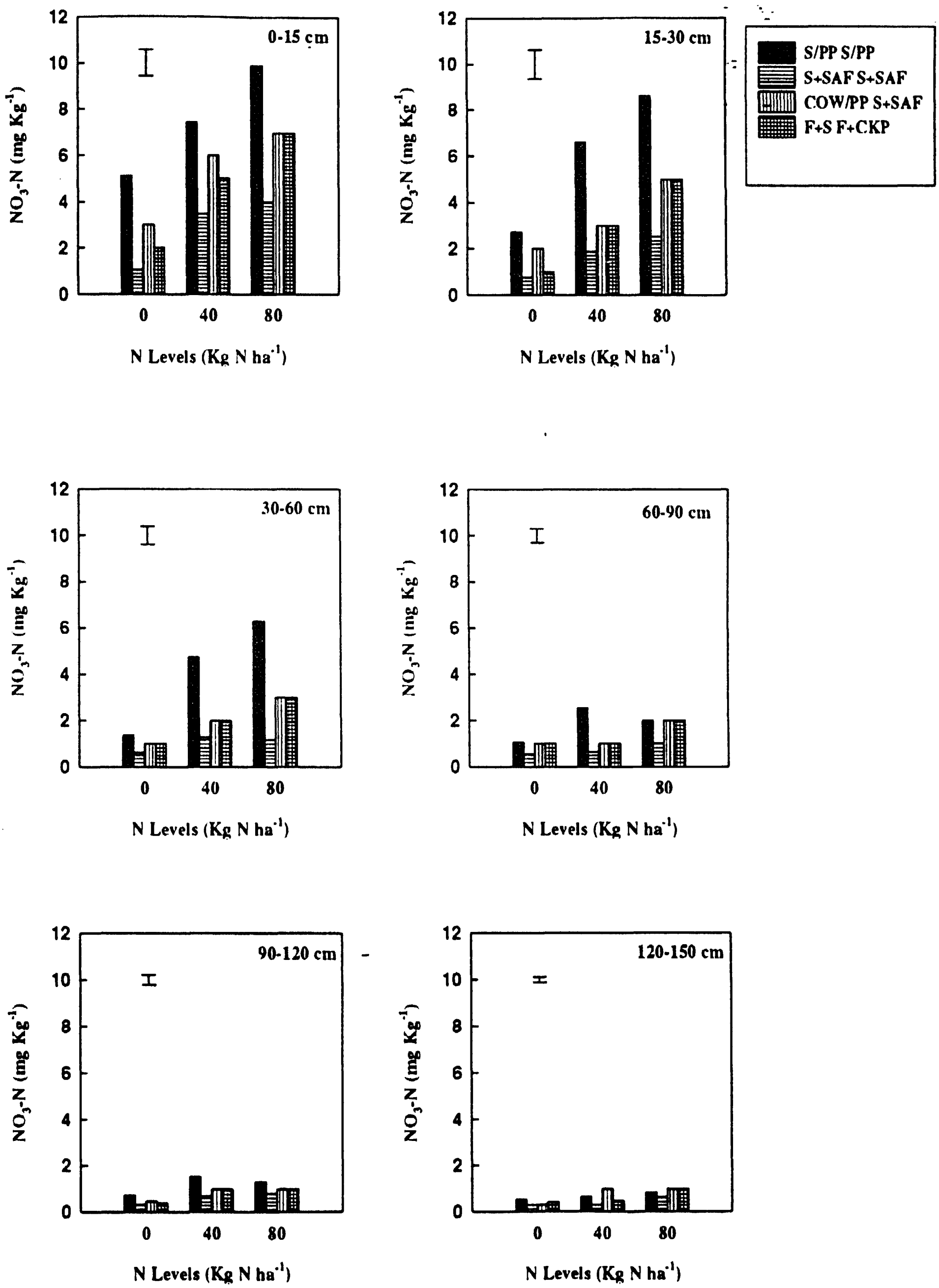

Figure 26 Effect of cropping systems rotations and nitrogen application on NO_3 content of the soil.

DISCUSSION

CHAPTER V

DISCUSSION

Organic matter plays an important role in soil management and crop productivity. It is the major natural source of inorganic nutrients particularly N and microbial energy. Its is important the soil to have an appreciable amount of organic matter, especially in soils with high sand or clay content (Rasmussen and Harold 1991). Therefore, it is very important to quantify root organic matter inputs because this will give an idea on how much dry matter has been left below-ground by crops, which in turn will help budget nutrient requirements of the following crops in the subsequent seasons. Measurements of root dry weight for many field crops are scarce and many researchers do not take into consideration the contribution of roots in terms of organic matter, when estimating productivity and sustainability of the different cropping systems.

There is a marked difference in root dry matter between plant species and between different genotypes in the same species (Abdul Salam and Abdul Wahid 1993). All the crops in the different cropping systems rotations investigated in this experiment showed varied organic matter inputs. This in turn affects the overall root organic matter inputs of the systems.

Almost all the crops show increase in root biomass till flowering and later gradual decline. Roots grow slower and there are only few younger roots at later stages (Myers 1980; Kaigama et al. 1977. Differences in root dry matter between N0 and N80 of the 1994 sorghum were not significant at the early stages of root growth, but later the differences were significant. This could be due to the initial fertility of the soil in the N0 plots and plants might have used that fertility to have an early high growth rate, but as the plant reaches the flowering stage the plant's energy is diverted to the grain filling, therefore the roots get a lesser share of the photosynthates, (Wilson and Eastin 1982) which might explain the reduced growth of the roots in the N0 plots. In 1995 the differences in root growth were apparent at an early stage, because of the declined fertility level of the N0 plots.

Pigeonpea was intercropped with cowpea and sorghum. Characteristically pigeonpea is a slow growing crop at the initial stages of growth (Narayanan and Sheldrake 1976). Both cowpea and sorghum showed higher root dry matter than pigeonpea in the initial stages of growth, but after the harvest of the companion crops, pigeonpea roots started growing vigorously. Differences in root dry matter between pigeonpea intercropped with sorghum and pigeonpea intercropped with cowpea were not significant in any stage in the first year (1994). However, in the second year (1995) the differences were significant in the later stages of growth, where pigeonpea intercropped with cowpea showed higher root dry matter than pigeonpea intercropped with sorghum, this could be due to the longer duration in which sorghum is associated with pigeonpea (20-25 days more) compared to cowpea, and also sorghum roots are more extensive and deeper than to cowpea roots. Therefore, there is a chance that these roots compete with pigeonpea roots. In 1994 highest root dry matter was obtained at 108 DAS, whereas at 1995, highest root dry matter was obtained in 147 DAS. this was probably because of the slow growth of pigeonpea in the early stages in this year, and therefore maximum root growth period was reached at a later stage.

Safflower was grown in the postrainy season in plots that were grown in the rainy season. Differences in root dry matter between plants in the N0 and N80 plots were significant in all the stages of growth. These differences were higher in the first year than in the second year. In the second year postrainy season the overall growth of the crops was lower than in the postrainy season of 1994.

The plant needs an extensive root system to support the above-ground parts by adequately supplying the much-needed nutrients and water. The results show that for most of the crops, 60-70% of their roots are found in the upper (0-60 cm) layer. This means that most of the root dry matter inputs are found in the upper layers. Blum et al. (1977); Narayana and Sheldrake (1976); Zade et al. (1981) reported similar findings from their work on sorghum and pigeonpea.

Results in Table 4 show that, when no fertilizer was applied the systems with legumes contribute a substantial amount of root organic matter to soil compared to non-leguminous or fallow systems, but if fertilizer N is applied the non-leguminous system also gives a fairly high amount of root organic matter.

Leaf fall of pigeonpea and cowpea was estimated. Literature on cowpea fallen leaves was not available for comparison. The results obtained from pigeonpea were comparable with the findings of (Sheldrake and Narayanan 1979). In this study fallen leaves dry weight account around 22% of the total dry matter for pigeonpea and 4% for cowpea, whereas roots account for around 12% of the total biomass including fallen leaves for pigeonpea and 10% for cowpea. The potential for fallen leaves biomass to contribute N to a subsequent crop can be considerable since they represent the single largest source of vegetative N remaining in the residues and because their high N content and low C/N ratio favours mineralization (Peoples and Craswell 1992).

Sorghum N uptake shows initially a slow accumulation of N followed by a rapid rate of accumulation which coincides with the rapid plant growth, and a slow rate again as the plant enters the maturity stage. Similar N uptake patterns were observed by Tinker (1978); Pearson and Muirhead (1984), in which sorghum crop showed high rate of N uptake at early stages of growth and the rate reduced after grain filling stage. This is because of N concentration in the young plants are initially high and characteristically decline as the plant ages and accumulates dry matter (Myers et al. 1987).

In the second year rainy-season sorghum showed a rapid decline of N uptake in the later stages of growth, this could be due to the loss of N because of the high rainfall during the season (Wetselaar and Farquhar 1980).

In the second year, the postrainy season sorghum and safflower crops which were grown in the continuously non-fertilized plots showed markedly less N uptake, whereas the same crops grown in the continuously fertilized plots showed either more or similar increase of N uptake. In an experiment in which crops received N fertilizer rates similar to the rates used in this experiment Roy and Wright (1972) found reduction in soil N in the unfertilized plots, this in turn affected the biomass production and N uptake of the crops. Maximum N accumulation or uptake can be delayed by the lack of adequate N supplies (Jordan et al. 1950; Russelle et al. 1981; 1983). This might explain the delay of the maximum N uptake period for some of the crops in the second year, particularly in the unfertilized crops.

In both years shoot biomass and N uptake of rainy-season sorghum was higher than postrainy season sorghum shoot biomass of N uptake. Apart from the different varieties used, there was also a variation in the amount and rainfall distribution in both seasons in both years.

Even though safflower had a lower shoot biomass than postrainy season sorghum, its N uptake was comparable with that of postrainy season sorghum.

Pigeonpea was intercropped with cowpea and sorghum. The results indicate that both cowpea and sorghum had higher N uptake than pigeonpea till their harvest. Pigeonpea had initially slow growth, due to it being a C3 plant and also due to shading, but after the harvest of the companion crops, pigeonpea grew more vigorously and its N uptake increased. Since N fertilizer was not applied to the pigeonpea it is assumed that its N uptake comes either from soil N or biological N fixation. Tobita et al. 1994 found that when N was exhausted by a companion crop, the pigeonpea intercrop crop increased its dependency on atmospheric N_2 fixation. Pigeonpea intercropped with cowpea showed higher N uptake than pigeonpea intercropped with sorghum. This could be due to cowpea being another legume crop which can fix part of its N requirements, growing less vigorously than sorghum, and being associated with the pigeonpea for less duration than sorghum.

Cowpea N uptake was higher in the second year than the first year. This could be due the greater growth of the crop in the second year, and resultant higher biomass than the first year.

The amount of N present in roots of different crops vary greatly with species, cultivar, and the environment in which they were produced. Mostly N accumulation in roots follows more or less the pattern of root dry matter accumulation. The rate of increase in root N content is slow compared to the rate of N accumulation by the above-ground plant parts. Fertilizer N application does effect N content of the roots. Root N content of sorghum in the first year (1994), started in a lower rate and gradually increased and later on slowed down, but in the second year it has started in a higher rate and gradually declined particularly in N0 plots, this could be due the initial high rate of root growth which decreases as the plant approaches the grain filling stage.

Postrainy season sorghum and safflower plants which received 80 kg N ha^{-1} showed higher root N content in 1995, whereas the crops which did not receive N fertilizer in both years showed lower root N content, in keeping with the declining fertility of the plots. Cowpea and chickpea both showed higher root N content in the second year compare to the first year, perhaps due the better root nodulation of these crops.

Systems in which legume crops are grown, leave behind roots with higher N content than non-legume crops. Because of their capacity to fix atmospheric N_2 in root nodules, leguminous crops contain higher amounts of N in their roots than cereals which may have high root biomass but with low N content (Goh and Haynes 1986). This might explain results presented in Table 5 which show that, the systems S/PP S/PP and S+SAFF COW/PP and its mirror image COW/PP S+SAFF return to the soil around 14 kg N ha^{-1} through their roots. F+S F+CKP and F+CKP F+S systems do not contribute much to the soil in terms of N return through roots. 70-80% of the roots of the different crops were found in the upper (0-60 cm) soil layer, containing considerable amounts of N.

When these roots decompose, part of their nutrients are released. These nutrients may not be available for the crops which follow them immediately because of the time required for the roots to decompose which in turn depends on the C/N ratio of the roots. The nutrients become available to other plants following the breakdown of tissue and its mineralization by soil microbes. The amount of N which is taken up from the legume residue by a following crop is determined by the proportion which is mineralized and the efficiency with which the crop utilises the mineralized N in the soil (Wood and Myers 1987). The proportion of residual N mineralized to N is determined by factors such as the quality of the residue expressed as C/N ratio, temperature and soil water status. This mineralized N can be taken into consideration while studying nutrient balance of the soil or estimating nutrient requirements of the following crops. Investigations carried out by Frankenberger and Abdelmagid (1985); Nnadi and Balasubramanian (1978) showed that roots and leaves of most leguminous crops decompose between 90-150 days, if adequately incorporated in to the soil.

Cowpea and pigeonpea contribute also to the soil N pool by way of N return through fallen dry leaves, which can be incorporated into the soil. These leaves while decomposing release their N, and it can be made available to the subsequent crops. Pigeonpea contributes around 40 kg N ha^{-1} through fallen leaves which may decompose in around 90 days (Nnadi and Balasubramanian 1978).

The results show that there is an effect of the preceding legume crops on the following cereal crop, and a combination of intercropped cowpea and pigeonpea gave an effect of equivalent to 35-38 kg N ha^{-1}. Rego and Burford (1992); Weil and Samaranyake (1991); Ahlawat et al. (1981) reported similar observations. In their systems, N uptake of the subsequent sorghum crop was increased by 20 kg N ha^{-1}. These results show that around 40 kg ha^{-1} fertilizer N can be saved by including legumes in the system.

With safflower, when no fertilizer was applied, safflower yield in the system COW/PP S+SAFF was higher than in the system S+SAFF S+SAFF. This indicates that inclusion of legumes gave a fertilizer equivalent of 10-15 kg N ha^{-1} and the uptake of N by safflower increased by 6 kg N ha^{-1}. The response in the case of safflower was not much compare to the response of rainy-season sorghum, this could be due to the non-legume crop which was grown after the legume and before safflower. Similar results were reported by Rego and Burford 1992.

Results in Table 7 and 9 show that chickpea had higher NHI than the other crops in both years, this greater partitioning of dry matter into seeds enables chickpea to outyield pigeonpea in many areas, in spite of the fact that their growing season is shorter and plants are smaller. Most of the N taken up by the different crops is found in the grain.

Fallen leaves of these crops were found to contribute a considerable amount of N (pigeonpea 40 and cowpea 2.07 kg N ha^{-1}). Nitrogen content of the fallen leaves represented 20-30% of the total N taken up by the plant. Kumar Rao et al. 1987 reported similar results.

Assuming from Sheldrake and Narayanan 1979; Kumar Rao and Dart. 1987 that only 50% of the roots can be recovered, then pigeonpea fallen leaves and roots return 53 kg N ha^{-1} in 1994 and 41 kg N ha^{-1} in 1995. Cowpea returned 7 and 12 kg N ha^{-1} in 1994 and 1995 respectively. Chickpea 4.5 and 9.8 kg N ha^{-1} in 1994 and 1995 respectively. This indicates that these plant parts should be always taken into consideration while estimating N contribution by the legumes.

There are different reports on the amounts of N that these legume crops can fix and proportion of N from fixation (P_{fix}). Table 1 show some of the values obtained from the literature.

The results reported in the present report are within the range reported in the literature. Pigeonpea net N balance reported in the present work is +92 which is higher than the balance reported in the literature, this is because, almost all the work done on pigeonpea N balance, fallen leaves were not taken into consideration except for the work of Kumar Rao and Dart 1987. They examined a wide range of pigeonpea cultivars and eventually N content of fallen leaves was taken into consideration but the amount they reported ranged from 8-24 kg N ha^{-1}, whereas in the present work, N content of the pigeonpea fallen leaves was found to be 40 kg N ha^{-1}.

Direct N transfer from pigeonpea to sorghum was not studied in this experiment. However, in a similar system Kumar Rao et al. 1987; Tobita et al. 1994 could not find any evidence which might suggest direct transfer from the legume crop to sorghum, but they found that some N in the underground plant parts of pigeonpea was available to growth of a succeeding crop.

Results of the soil analysis show that there was no change in the soil pH or electrical conductivity (EC). It is always difficult to find changes in soil pH or EC in a short term experiment like. Long term changes of the soil pH and EC were reported in the literature (Ahlawat et al. 1981). Short-term changes of soil total N after field crop legumes are also difficult to observe. However, there are reports which suggest short term changes of the soil total N after pasture crops. Long-term changes of the soil total N after field crops were observed by several researchers (Rowland 1987). One of the most consistent effects of crop legumes is to increase plant-available NO_3-N in the soil.

The extra nitrate which was found can be from several possible sources-the sparing effect which comes from reduced use of soil nitrate, from mineralization of fallen plant leaves which are rich in N, or from recycling of N from sloughed material from below ground parts (roots or nodules).

SUMMARY
&
CONCLUSIONS

CHAPTER VI

SUMARY AND CONCLUSIONS

Organic matter plays an important role in soil management and crop production. It is the natural source of mineral N. The results of the experiments carried out show the importance of quantifying the organic matter inputs to the soil by different cropping systems rotations. The results show that in the absence of N fertilizers, S/PP S/PP can deposit in the soil a substantial (2395 kg ha^{-1}) amount of root organic matter on the other hand the non-leguminous system S+SAF S+SAF contribute 1652 kg ha^{-1} of root organic matter to the soil. But if the crops are given adequate N fertilizer the results show that almost similar amounts of root can be deposited even by the non-leguminous system. The same findings were observed in the case of N content of the roots deposited to the soil by the different crops in the different systems. Legumes can also contribute to the organic matter of the soil by way of fallen dry leaves, which if incorporated into the soil mineralize and contribute substantial amounts of N.

The N uptake of the crops in the different systems were varied according to the N level and the season. In 1995, kharif sorghum N uptake increased compared to 1994, but the uptake declined highly after flowering probably due the high rainfall. In general, 1994 rabi crops had higher N uptake than 1995 rabi crops due the lack of rainfall in the later part of the season.

There was residual effect of the legumes depending on the cropping system. COW/PP was found to contribute about equivalent to 38 kg ha^{-1} of N fertilizer to the succeeding rainy season sorghum, whereas the same system contributes to equivalent 10-15 kg N ha^{-1} to the safflower which follows the sorghum.

The amounts of N fixed by different legume crops was also estimated. Pigeonpea was found to fix between 88 and 148 kg N ha^{-1}, whereas chickpea can fix between 27 to 74 kg N ha^{-1}, and cowpea can fix 32-52 kg N ha^{-1} . The net N balance of the legumes depends on the reference crop used and the method of N estimation used. In this experiment N-difference method was used and the results show that pigeonpea has a balance of +92 kg N ha-1 if kharif sorghum is used as a reference crop. It worth mentioning that the sorghum variety used was lesser in duration the pigeonpea, therefore it may overestimate the N balance of the pigeonpea.

Short duration crop rotation experiments such the one carried out in this investigation, generally do not change the soil organic matter or total N. However, changes in soil NO_3-N can be observed in such short term rotation experiments. S/PP S/PP system was found to increase soil NO_3-N compared to the non-leguminous system or fallow systems.

From this study it can be concluded

1. Legumes contribute large amounts of root organic matter which 70-80% of it, is deposited in the upper (0-60 cm) layer of the soil. This roots return to the soil substantial amount of N which can be available for the following crops after its mineralization.

2. Non-leguminous crops also can return to the soil high amounts of root organic matter if adequately fertilized.

3. Legumes also drop considerable amount of dry leaves which if incorporated to the soil can be a source of mineral N for the succeeding crops as they contain reasonable amount of N.

4. Inclusion of legumes in the rotations can contribute fertilizer N equivalent of 40 kg ha^{-1} to the succeeding rainy-season sorghum and the N uptake of sorghum can be increased by 20 kg N ha^{-1}.

5. Grain yield and dry matter of sorghum was increased due to the inclusion of legumes in the cropping system.

6. Legumes can fix considerable amounts of N, but care should be taken with regard to the method used for calculation.

7. Also care should be taken while calculating the net N balance of the different legumes, particularly the selection of the reference crop, because the amounts found may not reflect the true situation of the system.

8. Short term changes of soil total N and organic C are unlikely, but changes in soil NO_3-N can be observed, which might come from several sources such as sparing effect which come from reduced use of soil nitrate by legumes.

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APPENDIX

Appendix 1. Climatological observations at ICRISAT Asia Center during the experimental period (1994-1996).

DATA FOR THE MONTH..... 6 YEAR...... 1994

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	3.0	10.4	40.0	24.0	74.0	37.0	9.3	8.4	21.9
2	3.4	8.7	39.5	23.5	74.0	30.0	7.6	7.3	21.4
3	0.0	11.1	40.0	25.5	67.0	26.0	6.2	9.4	24.6
4	0.0	10.6	38.5	24.5	73.0	31.0	11.5	10.0	23.0
5	0.0	12.2	38.0	27.0	63.0	31.0	12.6	11.0	23.6
6	0.0	13.9	38.0	24.5	64.0	31.0	18.8	11.5	23.1
7	0.0	11.8	37.0	26.0	60.0	29.0	12.3	11.2	26.1
8	0.0	11.6	38.0	26.0	68.0	33.0	15.0	9.5	24.0
9	8.4	9.3	37.5	24.0	87.0	33.0	14.2	4.3	19.3
10	43.0	11.6	36.4	21.9	97.0	41.0	16.4	5.9	22.0
11	18.0	6.6	30.0	22.5	90.0	70.0	13.6	0.8	14.2
12	26.8	5.3	31.4	23.0	92.0	63.0	13.8	3.9	16.5
13	0.0	5.1	31.5	23.5	84.0	61.0	18.8	1.6	12.8
14	0.0	6.0	31.5	23.5	85.0	57.0	21.5	0.3	4.6
15	0.2	4.5	30.0	23.5	84.0	62.0	16.9	0.0	3.2
16	4.2	3.2	28.5	23.0	87.0	72.0	17.9	0.0	3.0
17	0.0	7.2	32.0	22.6	78.0	61.0	22.4	3.5	14.1
18	15.4	6.6	33.0	22.8	92.0	46.0	18.5	5.6	15.0
19	0.0	5.6	30.0	23.0	88.0	59.0	17.1	0.7	5.1
20	0.0	5.8	30.5	23.5	81.0	56.0	18.6	0.2	4.7
21	0.0	8.8	33.0	24.0	79.0	50.0	22.5	1.3	17.0
22	4.0	5.5	30.5	23.0	81.0	53.0	15.6	0.0	4.2
23	0.0	5.1	30.0	22.5	82.0	56.0	16.5	0.2	4.8
24	0.0	7.5	32.0	23.5	81.0	50.0	18.5	6.3	20.2
25	6.6	8.8	33.5	23.0	88.0	41.0	16.8	8.4	21.2
26	3.4	7.5	33.0	23.2	84.0	48.0	16.2	5.3	19.3
27	0.0	7.4	33.0	24.0	81.0	39.0	19.3	2.0	17.4
28	0.0	8.4	33.0	23.4	84.0	42.0	23.9	2.8	15.7
29	1.0	5.1	29.8	22.5	87.0	59.0	20.6	0.1	11.5
30	7.0	5.2	30.5	22.4	87.0	92.0	13.0	0.1	11.1
MEAN	144.4	236.4	33.7	23.6	80.7	48.6	16.2	4.4	15.5

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS, NOT MEANS
PLEASE NOTE THAT -99.9 STANDS FOR DATA NOT YET ENTERED

DATA FOR THE MONTH..... 7 YEAR...... 1994

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	8.1	32.5	23.5	84.0	52.0	12.0	5.5	21.8
2	0.0	8.3	32.5	23.5	79.0	53.0	20.8	4.6	18.4
3	11.0	2.4	29.0	21.5	98.0	61.0	13.6	0.0	10.5
4	21.6	1.2	23.5	21.5	96.0	98.0	16.1	0.0	3.6
5	1.3	3.8	25.5	20.0	97.0	72.0	13.4	0.0	11.0
6	0.0	5.8	32.0	22.0	90.0	49.0	13.8	9.1	23.0
7	0.0	8.9	33.0	24.0	81.0	46.0	17.6	11.3	25.8
8	15.7	6.1	31.5	22.0	97.0	54.0	19.2	2.4	16.9
9	0.4	4.5	29.0	23.0	87.0	79.0	19.3	0.4	10.9
10	3.1	2.1	27.0	22.0	95.0	83.0	20.2	0.0	8.1
11	2.2	0.7	24.8	22.5	91.0	89.0	22.1	0.0	6.6
12	5.2	2.1	26.0	21.8	97.0	89.0	22.3	0.0	8.4
13	2.0	5.3	28.5	21.5	88.0	72.0	24.8	0.0	13.4
14	2.4	3.4	28.0	21.5	88.0	86.0	23.3	0.0	12.0
15	9.3	4.0	29.0	22.5	90.0	70.0	19.2	3.2	13.5
16	0.8	5.9	30.0	23.0	87.0	72.0	20.8	3.4	15.6
17	0.0	7.0	32.0	22.8	88.0	65.0	18.1	4.5	15.8
18	0.0	5.5	31.5	22.5	88.0	65.0	21.2	2.5	16.3
19	1.4	6.4	31.0	23.0	87.0	58.0	19.2	4.0	16.3
20	14.2	4.4	30.5	23.0	88.0	55.0	17.6	0.1	10.0
21	0.0	5.0	29.0	23.0	87.0	66.0	18.4	0.0	14.1
22	3.0	8.2	31.0	22.5	87.0	59.0	17.7	2.7	15.7
23	5.0	5.6	31.0	22.5	87.0	83.0	15.7	4.8	17.6
24	9.8	4.4	29.8	22.0	97.0	82.0	12.5	2.9	12.5
25	0.0	3.5	29.0	23.0	87.0	68.0	16.0	1.1	14.3
26	10.0	4.3	29.0	22.5	90.0	68.0	13.4	1.1	14.7
27	0.5	4.8	30.0	22.5	90.0	62.0	14.9	6.3	19.0
28	1.0	3.8	29.0	22.5	91.0	75.0	11.0	1.1	11.9
29	14.0	3.2	29.5	22.5	91.0	68.0	12.8	0.1	11.2
30	0.0	3.6	28.3	22.4	88.0	70.0	15.3	0.0	9.4
31	9.0	5.0	29.5	22.5	91.0	70.0	17.8	0.6	14.0
MEAN	142.9	147.3	29.4	22.4	89.7	69.0	17.4	2.3	13.9

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
PLEASE NOTE THAT -99.9 STANDS FOR DATA NOT YET ENTERED

DATA FOR THE MONTH...... 8 YEAR...... 1994

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	3.2	27.5	23.0	88.0	73.0	9.3	0.0	12.1
2	0.3	4.0	28.0	22.6	87.0	73.0	15.6	0.4	8.3
3	0.0	4.2	30.0	22.5	87.0	61.0	7.3	1.3	16.2
4	0.0	4.6	30.0	23.0	85.0	63.0	12.9	0.0	13.3
5	0.0	5.2	30.5	22.0	83.0	59.0	13.9	1.3	18.0
6	0.0	8.0	32.5	22.0	83.0	48.0	13.1	9.7	23.8
7	0.0	9.0	32.0	22.0	76.0	51.0	13.8	8.6	24.2
8	0.0	6.6	32.0	24.0	76.0	43.0	12.8	7.0	22.2
9	0.0	7.0	31.0	23.5	76.0	51.0	11.5	0.1	15.2
10	7.0	4.6	31.5	21.8	96.0	47.0	11.1	0.8	15.7
11	20.4	2.6	26.0	21.5	98.0	77.0	11.7	0.0	7.9
12	9.6	0.8	24.5	21.5	98.0	91.0	11.3	0.0	4.8
13	0.0	2.1	25.3	22.2	91.0	84.0	11.0	0.0	8.5
14	1.4	4.4	30.0	21.2	97.0	68.0	9.3	5.9	16.4
15	0.0	4.4	30.5	22.5	92.0	64.0	7.5	3.6	17.8
16	0.0	5.3	31.0	22.0	91.0	56.0	10.7	5.0	20.2
17	4.0	4.6	30.0	22.5	88.0	71.0	13.3	2.5	15.6
18	26.2	4.6	29.0	21.5	96.0	65.0	15.9	0.3	11.9
19	22.6	2.2	28.0	21.5	91.0	73.0	14.4	0.0	10.4
20	0.0	4.3	29.5	21.5	91.0	63.0	12.8	5.2	18.4
21	0.0	5.6	31.0	22.5	87.0	60.0	9.5	9.0	20.9
22	9.0	4.0	29.5	22.5	98.0	69.0	8.3	1.2	14.1
23	37.0	1.3	25.0	22.5	93.0	90.0	8.9	0.0	6.8
24	0.0	4.6	30.0	22.5	91.0	69.0	10.1	8.3	21.2
25	2.0	3.7	29.5	22.0	95.0	72.0	11.2	3.5	14.7
26	40.4	4.4	26.0	21.5	95.0	98.0	11.0	0.0	7.4
27	7.0	2.6	27.0	21.2	90.0	80.0	16.8	0.0	11.9
28	0.0	4.0	26.5	21.2	91.0	81.0	17.9	0.2	11.4
29	6.0	4.2	28.0	21.5	91.0	87.0	14.9	4.1	16.5
30	2.4	3.6	28.2	22.0	88.0	71.0	13.0	0.9	12.8
31	1.6	1.6	26.0	22.0	93.0	92.0	17.4	0.0	6.9
MEAN	196.9	131.3	28.9	22.1	89.7	69.4	12.2	2.5	14.4

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
PLEASE NOTE THAT -99.9 STANDS FOR DATA NOT YET ENTERED

DATA FOR THE MONTH..... 9 YEAR...... 1994

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.5	6.0	29.5	22.5	88.0	71.0	18.8	5.2	17.0
2	0.0	5.6	29.5	22.5	88.0	66.0	13.6	2.8	17.4
3	0.0	5.0	30.5	22.0	88.0	54.0	19.2	1.8	15.1
4	3.5	3.7	28.5	21.8	95.0	63.0	13.7	0.3	10.7
5	2.6	2.6	29.0	22.0	91.0	67.0	13.5	0.3	11.3
6	0.0	3.3	29.0	22.0	87.0	58.0	17.2	0.7	13.1
7	6.4	5.5	29.5	20.0	91.0	64.0	13.7	1.6	15.4
8	0.0	5.7	31.5	21.0	91.0	53.0	13.1	10.2	21.4
9	0.0	7.1	31.8	22.5	90.0	55.0	13.1	9.7	23.2
10	0.0	5.7	31.5	21.5	85.0	53.0	9.8	8.4	22.4
11	4.4	6.8	32.0	21.5	91.0	52.0	8.6	9.4	23.0
12	0.0	4.8	31.0	22.5	95.0	56.0	5.7	9.8	23.9
13	1.0	6.2	30.0	23.5	97.0	63.0	7.1	7.2	20.2
14	5.6	4.0	31.5	22.0	95.0	53.0	7.7	7.7	20.9
15	0.0	5.7	30.0	20.2	86.0	64.0	8.2	9.8	22.4
16	0.0	5.5	30.0	22.0	95.0	50.0	7.2	7.2	19.1
17	10.0	4.3	29.0	21.5	96.0	64.0	10.6	0.7	12.2
18	26.0	3.0	29.0	21.4	93.0	68.0	14.9	2.5	13.5
19	0.0	3.2	29.0	20.5	86.0	65.0	10.7	5.4	18.6
20	0.0	5.3	30.2	19.5	84.0	49.0	8.6	9.6	24.6
21	0.0	4.0	29.5	17.0	91.0	57.0	7.8	9.3	19.5
22	0.0	4.8	29.5	18.5	84.0	61.0	5.8	7.5	21.2
23	0.0	6.0	30.5	19.8	86.0	47.0	5.3	10.1	23.6
24	0.0	5.2	31.0	18.6	85.0	42.0	4.1	8.4	19.8
25	0.0	4.4	32.5	20.5	91.0	42.0	4.3	8.4	18.6
26	6.0	3.6	32.0	21.5	88.0	56.0	6.5	5.5	16.5
27	0.0	3.0	30.0	22.0	87.0	60.0	3.3	2.3	15.5
28	0.0	6.0	32.0	19.5	89.0	41.0	6.1	8.2	20.8
29	0.0	5.8	31.8	18.2	91.0	35.0	5.2	9.1	21.0
30	0.0	5.9	31.5	18.5	84.0	40.0	5.9	10.3	22.0
MEAN	66.0	147.7	30.4	20.9	89.6	55.6	9.6	6.3	18.8

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DATA FOR THE MONTH...... 10 YEAR...... 1994

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	4.2	30.8	22.5	87.0	44.0	6.1	4.4	16.4
2	2.0	3.6	32.0	21.0	95.0	48.0	8.7	7.9	21.0
3	20.0	6.0	31.0	21.2	96.0	55.0	6.8	7.7	18.2
4	0.0	2.4	29.0	21.5	98.0	69.0	3.3	1.5	13.6
5	2.0	2.5	29.0	22.5	95.0	86.0	8.2	2.5	14.1
6	77.0	0.2	27.0	21.5	98.0	73.0	16.9	0.1	9.9
7	62.6	0.2	27.0	21.2	98.0	98.0	12.5	0.0	3.6
8	0.0	2.2	28.5	22.0	97.0	71.0	6.2	2.5	13.0
9	0.0	4.0	29.0	21.0	98.0	73.0	4.6	4.5	16.6
10	0.0	3.0	30.0	19.2	98.0	52.0	4.3	3.8	16.9
11	0.0	4.0	30.5	19.0	96.0	48.0	16.7	7.5	19.9
12	0.0	4.0	30.0	18.5	95.0	45.0	4.4	10.0	19.4
13	0.0	5.0	31.0	20.0	97.0	39.0	5.2	10.4	20.4
14	0.0	4.2	31.0	21.5	90.0	43.0	4.2	9.2	21.1
15	1.0	4.5	30.5	22.0	96.0	61.0	6.6	8.1	17.5
16	0.0	3.0	29.5	22.8	93.0	58.0	4.1	2.6	13.1
17	0.0	4.8	30.0	18.2	96.0	40.0	7.4	6.4	18.0
18	0.0	4.6	30.0	21.0	91.0	48.0	5.8	9.0	20.4
19	0.0	5.9	30.0	21.6	90.0	43.0	11.9	6.9	17.8
20	0.0	3.7	27.5	21.0	96.0	71.0	11.2	5.2	14.4
21	2.4	4.2	30.0	20.5	95.0	58.0	5.5	6.8	19.0
22	19.0	5.6	31.0	20.2	95.0	54.0	6.5	9.9	21.2
23	1.7	2.4	28.0	20.5	98.0	75.0	4.0	4.5	12.9
24	0.5	4.5	29.0	21.8	91.0	63.0	5.7	10.3	18.7
25	35.3	3.8	28.0	20.8	95.0	76.0	5.3	3.2	18.4
26	0.0	3.4	29.0	21.0	98.0	62.0	5.6	9.4	19.2
27	0.0	5.0	29.5	18.5	96.0	53.0	5.1	8.9	18.0
28	0.0	5.0	29.0	21.0	91.0	57.0	7.9	8.8	17.9
29	24.0	8.0	29.0	20.0	91.0	62.0	10.4	8.1	18.0
30	0.0	3.8	28.0	20.5	98.0	66.0	6.7	5.5	15.5
31	0.0	5.6	29.5	18.5	96.0	46.0	8.2	8.0	19.5
MEAN	247.5	123.3	29.5	20.7	95.0	59.3	7.3	6.2	16.9

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
PLEASE NOTE THAT -99.9 STANDS FOR DATA NOT YET ENTERED

DATA FOR THE MONTH..... 11 YEAR...... 1994

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	4.4	28.0	19.0	85.0	57.0	15.4	3.0	14.2
2	1.6	4.2	24.5	17.0	96.0	67.0	13.8	1.8	11.4
3	5.6	0.6	19.5	18.0	98.0	98.0	12.6	0.0	4.4
4	0.4	0.8	21.5	20.0	91.0	98.0	7.2	0.0	6.0
5	0.0	4.4	27.5	20.2	88.0	66.0	9.1	5.6	14.7
6	2.0	3.7	25.0	20.0	98.0	84.0	5.2	0.7	9.5
7	0.0	2.0	27.5	19.0	98.0	70.0	9.3	1.5	12.7
8	0.0	4.0	28.5	17.5	98.0	59.0	6.6	9.3	18.2
9	0.0	4.7	28.0	16.5	98.0	56.0	8.8	8.7	18.6
10	0.0	4.6	27.5	16.5	98.0	55.0	7.0	8.6	17.9
11	0.0	4.0	28.0	17.5	96.0	53.0	8.2	9.7	18.5
12	0.0	6.2	29.0	17.0	98.0	52.0	5.6	9.3	18.4
13	0.0	3.8	29.0	17.5	98.0	50.0	3.7	7.6	16.8
14	0.0	3.6	29.0	17.0	98.0	52.0	6.4	6.2	15.5
15	0.0	3.4	28.0	18.2	98.0	55.0	7.2	6.9	16.6
16	0.0	4.8	28.0	17.8	96.0	53.0	6.8	8.2	17.8
17	0.0	4.1	27.5	18.0	91.0	51.0	7.2	5.7	14.7
18	0.0	4.7	28.5	16.5	98.0	51.0	7.8	9.9	17.7
19	0.0	4.0	28.0	13.5	88.0	50.0	6.9	7.0	14.3
20	0.0	5.6	27.0	10.2	91.0	39.0	7.7	10.1	18.0
21	0.0	4.0	27.5	15.0	98.0	32.0	4.9	9.9	19.0
22	0.0	2.8	26.8	14.5	98.0	51.0	6.9	5.6	12.8
23	0.0	3.6	28.0	13.5	98.0	44.0	5.4	7.5	16.1
24	0.0	5.7	27.5	11.0	89.0	36.0	6.8	9.5	18.1
25	0.0	5.5	27.0	10.5	91.0	34.0	7.4	9.9	18.6
26	0.0	4.0	26.5	11.0	93.0	42.0	6.1	10.1	18.4
27	0.0	4.8	26.5	9.0	98.0	42.0	5.2	9.5	18.4
28	0.0	3.2	27.0	10.6	98.0	41.0	4.9	9.8	18.7
29	0.0	3.9	28.0	11.5	98.0	37.0	5.1	10.1	18.1
30	0.0	3.6	28.5	13.0	98.0	33.0	4.8	9.7	17.3
MEAN	9.6	118.7	27.1	15.6	95.3	53.6	7.3	7.0	15.7

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
PLEASE NOTE THAT -99.9 STANDS FOR DATA NOT YET ENTERED

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	9.0	29.5	13.0	94.0	38.0	5.0	9.0	3.8
2	0.0	3.2	29.0	13.2	96.0	37.0	4.6	9.9	17.3
3	0.0	4.6	28.0	12.0	98.0	40.0	5.4	9.4	17.1
4	0.0	2.4	27.0	12.5	96.0	33.0	5.3	9.4	17.7
5	0.0	3.9	27.0	12.0	97.0	34.0	5.1	9.5	17.6
6	0.0	4.5	26.8	11.4	98.0	29.0	5.7	10.0	17.6
7	0.0	4.1	26.3	9.5	93.0	27.0	5.0	9.8	17.7
8	0.0	4.2	26.5	10.0	95.0	36.0	5.8	10.3	17.8
9	0.0	3.4	27.5	10.0	95.0	33.0	4.2	10.0	16.6
10	0.0	4.1	29.0	9.5	89.0	29.0	5.5	10.5	17.4
11	0.0	3.8	29.0	10.5	87.0	24.0	4.3	10.4	17.4
12	0.0	3.1	29.5	10.0	88.0	29.0	4.4	9.7	17.4
13	0.0	4.4	29.5	11.0	93.0	27.0	5.6	10.4	18.0
14	0.0	4.8	27.5	11.5	93.0	34.0	6.8	10.4	18.3
15	0.0	3.2	27.5	11.5	95.0	35.0	4.1	10.1	17.6
16	0.0	4.2	27.5	10.2	98.0	34.0	5.8	10.3	18.1
17	0.0	4.1	26.8	10.0	88.0	34.0	6.7	10.1	17.9
18	0.0	4.0	27.0	12.5	96.0	36.0	8.2	10.0	17.8
19	0.0	4.4	27.0	11.0	96.0	36.0	6.7	9.8	17.2
20	0.0	4.0	27.0	9.5	84.0	39.0	6.0	9.8	17.3
21	0.0	4.1	27.0	10.0	93.0	30.0	5.0	10.2	17.8
22	0.0	3.9	26.5	7.5	92.0	36.0	5.4	9.9	16.9
23	0.0	3.4	25.5	7.0	92.0	18.0	4.8	10.4	18.5
24	0.0	3.3	26.0	7.5	81.0	23.0	4.4	10.1	16.2
25	0.0	4.5	26.5	7.0	95.0	25.0	6.8	9.1	16.0
26	0.0	4.1	25.0	7.8	92.0	31.0	6.2	7.6	15.6
27	0.0	4.1	25.5	8.0	93.0	31.0	6.4	9.3	17.4
28	0.0	4.1	26.0	12.5	94.0	34.0	9.5	9.7	17.9
29	0.0	4.1	26.0	11.5	98.0	46.0	7.9	9.1	16.7
30	0.0	3.1	26.0	10.2	93.0	40.0	5.0	9.4	16.7
31	0.0	3.7	26.5	9.5	84.0	28.0	5.2	8.2	16.1
MEAN	0.0	125.8	27.1	10.3	92.8	32.5	5.7	9.7	16.9

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
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DATA FOR THE MONTH..... 1 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	3.3	27.0	9.5	77.0	33.0	4.5	10.3	17.5
2	0.0	3.1	27.5	10.5	98.0	29.0	5.1	9.3	17.2
3	0.0	3.3	28.0	10.8	93.0	34.0	4.4	9.3	17.0
4	0.0	4.6	28.5	12.0	94.0	29.0	9.0	9.8	17.4
5	0.0	5.4	27.5	14.0	96.0	26.0	13.2	10.2	18.5
6	0.0	5.4	26.0	18.5	64.0	44.0	16.9	9.9	17.9
7	0.0	2.4	23.8	17.5	91.0	53.0	14.2	1.2	7.5
8	6.6	2.4	24.5	18.6	98.0	64.0	17.1	6.2	7.4
9	3.8	2.6	27.2	16.5	90.0	66.0	5.7	5.8	7.5
10	0.0	5.5	25.5	12.5	98.0	47.0	5.9	9.7	17.8
11	0.0	3.5	27.0	19.0	91.0	51.0	7.6	8.2	16.5
12	1.0	3.0	28.0	16.5	98.0	57.0	6.8	5.2	11.1
13	0.0	3.9	25.0	13.0	93.0	55.0	10.9	7.3	15.9
14	0.0	3.2	24.5	9.5	93.0	45.0	5.1	10.1	18.3
15	0.0	3.5	25.0	15.2	91.0	52.0	8.1	9.3	17.5
16	0.0	3.8	26.0	19.5	91.0	56.0	14.5	7.9	13.5
17	22.6	2.4	25.0	14.5	98.0	87.0	14.3	2.5	8.4
18	6.0	2.9	20.0	9.0	98.0	94.0	6.4	1.2	4.7
19	0.0	3.8	23.5	10.0	98.0	47.0	6.2	10.3	19.7
20	0.0	2.5	26.0	10.5	98.0	52.0	2.9	10.0	18.0
21	0.0	3.3	26.5	12.0	96.0	44.0	3.0	9.6	18.6
22	0.0	3.7	28.0	13.0	92.0	37.0	4.5	10.0	18.9
23	0.0	3.7	30.0	13.5	98.0	32.0	4.9	10.1	19.2
24	0.0	4.6	27.5	11.0	93.0	43.0	5.3	8.9	18.0
25	0.0	4.4	27.0	12.0	93.0	36.0	4.8	10.1	19.5
26	0.0	4.8	27.0	10.5	85.0	33.0	4.5	10.7	19.1
27	0.0	5.5	27.0	11.5	95.0	27.0	6.7	9.9	19.9
28	0.0	4.7	26.5	11.6	89.0	39.0	5.9	10.4	19.3
29	0.0	4.8	26.5	11.0	93.0	45.0	5.6	10.1	19.4
30	0.0	5.4	26.0	11.0	88.0	33.0	5.6	9.9	19.7
31	0.0	3.8	26.0	13.5	94.0	35.0	5.6	8.8	16.3
MEAN	40.0	119.2	26.2	13.2	92.4	46.0	7.6	8.5	16.0

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
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DATA FOR THE MONTH..... 2 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	4.4	27.0	13.5	98.0	46.0	9.4	9.0	17.2
2	0.0	4.0	28.5	15.5	90.0	47.0	8.5	9.2	17.9
3	0.0	5.6	28.0	16.0	90.0	43.0	7.3	8.0	16.9
4	0.0	5.8	28.5	16.5	91.0	47.0	13.5	10.1	17.8
5	0.0	6.5	29.5	17.5	85.0	40.0	14.4	10.4	19.3
6	0.0	4.0	30.0	16.5	96.0	41.0	10.7	10.0	19.3
7	0.0	4.9	28.0	14.5	98.0	53.0	8.7	10.1	18.2
8	0.0	4.4	29.0	15.5	94.0	49.0	5.8	9.4	18.0
9	0.0	4.5	30.0	17.0	94.0	45.0	4.4	8.9	17.7
10	0.0	5.8	31.0	16.8	94.0	35.0	6.2	10.3	18.7
11	0.0	5.5	32.2	16.0	90.0	32.0	5.0	10.4	18.6
12	0.0	7.0	32.0	16.5	89.0	29.0	8.5	10.2	20.1
13	0.0	7.9	32.5	16.5	75.0	23.0	11.6	10.6	20.2
14	0.0	7.6	32.5	15.0	86.0	19.0	8.0	10.5	20.4
15	0.0	6.8	32.0	15.0	88.0	21.0	8.2	10.7	20.5
16	0.0	6.0	30.0	14.5	89.0	36.0	5.6	10.5	20.4
17	0.0	6.0	29.5	16.5	90.0	29.0	5.3	9.8	20.7
18	0.0	8.0	33.0	18.5	54.0	35.0	9.9	9.5	18.4
19	0.0	5.6	32.0	13.5	86.0	26.0	5.0	10.1	20.8
20	0.0	5.7	32.0	13.6	79.0	27.0	4.4	9.0	19.7
21	0.0	6.3	32.0	13.0	83.0	18.0	5.7	10.6	20.6
22	0.0	5.0	32.6	16.0	83.0	27.0	4.3	10.6	19.7
23	0.0	6.3	34.5	17.5	53.0	24.0	7.4	10.2	19.7
24	0.0	5.6	31.5	16.0	90.0	32.0	6.3	9.5	19.8
25	0.0	7.2	33.0	18.2	64.0	30.0	6.6	10.7	19.3
26	0.0	7.8	31.5	20.0	91.0	35.0	12.1	10.1	19.6
27	0.0	7.4	33.5	18.5	78.0	31.0	10.1	10.2	19.6
28	0.0	8.0	32.5	15.0	63.0	19.0	6.6	10.5	20.8
MEAN	0.0	169.6	31.0	16.0	84.3	33.5	7.8	10.0	19.3

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
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DATA FOR THE MONTH..... 3 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	6.7	32.5	17.5	92.0	24.0	6.4	10.7	21.3
2	0.0	6.8	35.0	18.5	82.0	23.0	6.2	10.2	19.5
3	0.0	8.7	35.0	19.0	65.0	24.0	7.6	9.6	19.9
4	0.0	7.2	35.2	18.5	73.0	22.0	5.3	8.7	17.5
5	0.0	9.2	35.5	20.5	64.0	32.0	8.4	9.9	19.8
6	0.0	9.0	36.5	18.8	82.0	16.0	7.2	9.1	19.9
7	0.0	10.5	36.5	19.8	81.0	15.0	10.6	10.0	20.5
8	0.0	9.7	34.5	20.0	79.0	15.0	15.0	10.3	22.0
9	0.0	10.3	32.0	19.5	82.0	34.0	20.2	10.7	22.4
10	0.0	9.1	32.5	19.5	75.0	22.0	13.7	10.7	22.7
11	0.0	10.5	32.5	20.0	71.0	29.0	13.0	10.8	22.1
12	0.0	8.0	31.5	22.0	76.0	53.0	8.9	9.8	19.3
13	7.8	10.6	31.5	21.0	91.0	34.0	10.7	6.4	3.6
14	0.0	7.9	32.0	19.5	82.0	40.0	10.9	7.7	19.9
15	0.0	9.0	34.0	20.5	71.0	27.0	10.9	10.2	22.4
16	0.0	7.7	34.0	19.5	78.0	25.0	7.4	11.0	23.1
17	0.0	12.6	36.0	21.4	72.0	17.0	11.7	10.5	23.8
18	0.0	10.4	32.0	23.0	60.0	34.0	13.4	10.5	23.8
19	0.0	8.6	35.5	20.5	72.0	24.0	9.7	10.4	23.4
20	0.0	8.1	34.0	20.0	72.0	29.0	8.5	8.0	19.3
21	0.0	9.4	35.0	19.5	60.0	25.0	5.2	10.3	21.8
22	0.0	8.8	35.5	21.5	62.0	25.0	6.7	8.0	19.2
23	0.0	10.4	36.0	21.5	51.0	21.0	5.9	10.1	21.3
24	0.0	8.2	36.5	23.5	52.0	19.0	6.7	10.6	22.7
25	0.0	11.0	37.5	23.0	48.0	19.0	7.7	10.0	21.8
26	11.4	6.8	37.0	19.5	84.0	36.0	15.0	5.3	5.8
27	33.0	8.6	31.0	19.0	94.0	42.0	12.5	6.9	7.9
28	0.0	8.6	32.0	19.0	91.0	36.0	7.3	11.0	19.6
29	0.0	6.4	35.5	19.0	59.0	21.0	8.1	11.2	19.4
30	0.0	10.8	36.5	21.5	56.0	20.0	8.0	11.0	25.1
31	0.0	8.0	36.0	20.5	64.0	24.0	7.3	10.8	24.9
MEAN	52.2	277.6	34.4	20.2	72.3	26.7	9.6	9.7	19.9

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS, NOT MEANS
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DATA FOR THE MONTH...... [illegible] YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	9.7	35.5	21.0	62.0	24.0	7.5	10.6	20.8
2	0.0	9.8	36.0	23.0	61.0	34.0	7.8	10.2	21.0
3	0.0	7.3	35.5	23.0	85.0	28.0	10.4	8.4	19.4
4	0.0	10.0	35.5	23.2	66.0	28.0	10.3	7.9	20.1
5	0.0	7.2	36.0	22.0	67.0	24.0	9.0	7.2	18.4
6	0.0	10.4	35.5	21.2	69.0	29.0	14.2	9.3	20.2
7	0.0	10.0	36.0	23.5	70.0	21.0	10.8	10.7	21.3
8	0.0	11.7	38.0	23.0	64.0	23.0	8.8	10.5	22.6
9	0.0	11.2	38.2	23.0	50.0	25.0	11.1	10.9	24.2
10	0.0	11.5	37.5	26.0	66.0	19.0	13.1	10.0	23.8
11	0.0	12.0	36.8	19.0	76.0	22.0	15.2	11.0	24.0
12	0.0	11.5	35.5	18.0	46.0	19.0	10.2	11.2	24.2
13	0.0	12.2	37.0	20.5	53.0	17.0	8.3	11.1	24.4
14	0.0	10.8	38.5	22.5	57.0	15.0	8.4	10.5	23.5
15	0.0	12.2	38.0	22.5	70.0	24.0	11.9	10.5	24.0
16	8.8	7.2	36.6	18.0	84.0	35.0	12.6	6.1	20.3
17	0.0	6.0	34.5	21.5	81.0	33.0	5.8	11.1	19.0
18	0.0	8.7	35.5	21.0	79.0	28.0	8.0	10.8	19.9
19	0.0	10.6	37.0	23.5	65.0	22.0	9.2	10.6	22.0
20	0.0	10.2	36.0	24.0	63.0	22.0	8.7	10.6	20.8
21	0.0	10.8	35.5	24.5	50.0	30.0	11.3	10.3	20.4
22	0.0	9.3	37.5	24.0	52.0	21.0	7.1	9.2	22.6
23	0.0	10.7	38.0	24.5	58.0	25.0	8.6	8.4	23.8
24	0.0	10.0	38.0	22.5	62.0	24.0	6.6	9.1	23.6
25	0.0	9.6	39.0	24.0	54.0	19.0	6.8	11.2	24.8
26	0.0	9.8	39.5	24.5	55.0	20.0	6.2	10.1	25.1
27	0.0	10.1	38.5	24.0	57.0	23.0	10.3	7.0	24.0
28	0.0	12.0	39.0	24.0	69.0	21.0	11.0	10.9	24.2
29	0.0	12.2	38.5	24.0	63.0	23.0	10.7	11.1	24.3
30	0.0	11.1	38.0	22.5	69.0	34.0	10.0	10.8	24.0
MEAN	8.8	305.8	37.0	22.6	64.1	24.4	9.7	9.9	22.4

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DATA FOR THE MONTH..... 5 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	10.2	39.0	24.6	58.0	18.0	7.0	7.0	23.9
2	0.0	9.8	37.0	26.5	59.0	28.0	8.3	8.3	19.3
3	0.0	8.5	36.0	23.5	66.0	24.0	6.7	9.0	18.0
4	0.0	11.4	37.5	25.0	57.0	27.0	10.6	10.9	24.3
5	0.0	12.0	37.0	25.0	60.0	28.0	8.6	9.7	24.5
6	0.0	8.6	37.2	22.5	65.0	31.0	11.8	5.8	17.8
7	0.0	11.2	37.5	24.0	60.0	44.0	18.1	5.0	20.4
8	3.2	1.4	26.4	21.2	87.0	84.0	11.3	0.2	7.8
9	0.0	6.4	31.0	20.5	52.0	44.0	14.0	2.2	10.6
10	0.0	7.4	33.0	22.5	68.0	43.0	11.7	5.5	16.5
11	0.0	11.1	36.5	24.5	63.0	37.0	12.2	10.9	16.7
12	0.0	14.0	38.8	25.0	64.0	28.0	16.3	8.9	22.4
13	0.4	11.3	38.8	24.8	75.0	28.0	20.8	9.1	22.9
14	0.0	12.6	38.0	24.0	66.0	31.0	18.2	8.7	22.5
15	8.8	11.4	37.5	23.5	79.0	34.0	19.9	7.7	23.2
16	0.0	10.0	35.0	24.5	74.0	42.0	24.8	2.3	15.0
17	0.0	12.9	38.0	24.8	61.0	47.0	19.5	5.5	19.9
18	0.0	15.0	38.5	23.5	56.0	21.0	16.2	11.0	25.4
19	0.0	14.2	38.0	23.0	41.0	16.0	13.9	11.2	26.0
20	0.0	11.8	37.8	20.5	42.0	22.0	8.2	10.5	24.8
21	0.0	12.2	38.2	21.6	29.0	17.0	10.1	11.7	26.5
22	0.0	13.2	39.0	26.6	40.0	18.0	9.9	9.6	23.6
23	0.0	13.8	38.0	27.5	43.0	23.0	12.7	7.9	21.7
24	3.0	10.6	38.0	24.5	64.0	25.0	12.1	7.6	22.7
25	28.4	13.4	39.0	20.0	78.0	23.0	12.3	9.5	24.1
26	0.0	7.5	34.5	23.0	81.0	42.0	4.2	7.8	23.2
27	0.0	9.0	36.0	21.5	70.0	26.0	6.5	11.5	25.4
28	0.0	10.2	31.5	22.5	75.0	25.0	5.9	11.8	25.4
29	0.0	9.4	38.5	22.5	57.0	23.0	8.0	11.4	26.4
30	0.0	11.3	40.0	26.0	47.0	18.0	7.7	11.1	25.6
31	0.0	12.0	41.2	26.5	43.0	21.0	9.9	10.6	23.8
MEAN	43.8	333.8	36.9	23.7	60.6	30.3	12.2	8.4	21.6

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DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	14.0	41.5	27.5	65.0	21.0	16.7	11.3	25.2
2	0.0	14.1	42.5	25.0	40.0	13.0	10.4	11.0	25.2
3	0.0	14.6	43.0	25.0	33.0	10.0	11.3	11.4	25.6
4	0.0	15.0	42.5	28.2	40.0	14.0	10.9	11.3	24.5
5	0.0	17.4	42.5	27.0	59.0	15.0	25.8	9.7	24.9
6	0.0	14.8	41.0	27.6	60.0	20.0	11.5	1.9	17.3
7	0.0	17.4	41.5	29.0	49.0	19.0	18.2	5.1	21.8
8	0.0	19.2	41.5	25.5	64.0	19.0	28.1	10.5	24.6
9	0.0	16.4	41.0	27.5	59.0	24.0	19.7	10.8	25.6
10	0.0	17.6	40.8	27.2	54.0	18.0	20.6	10.6	25.3
11	0.0	16.4	38.5	27.5	52.0	28.0	18.1	6.8	23.2
12	0.0	13.8	38.2	28.0	51.0	32.0	15.6	9.0	23.3
13	2.6	11.4	39.0	26.0	72.0	29.0	13.9	8.1	21.5
14	0.0	10.7	38.5	24.0	73.0	33.0	11.3	9.1	21.9
15	0.0	12.0	37.5	25.5	70.0	32.0	11.6	12.1	25.8
16	0.0	9.1	38.0	25.2	67.0	40.0	12.3	10.9	23.4
17	59.0	14.8	39.0	23.0	98.0	32.0	11.9	9.7	23.9
18	1.4	2.4	29.5	23.5	78.0	72.0	8.3	0.5	10.3
19	0.6	7.0	33.6	24.5	77.0	50.0	13.3	7.0	22.0
20	0.0	9.4	35.0	25.0	66.0	45.0	16.0	5.4	21.3
21	7.0	7.9	35.0	23.5	87.0	43.0	14.7	7.6	22.1
22	29.4	4.4	32.5	20.0	95.0	61.0	15.5	0.3	11.8
23	0.2	3.4	28.5	23.5	87.0	80.0	11.2	0.0	8.6
24	13.4	4.0	31.0	22.0	88.0	62.0	12.0	2.8	19.9
25	0.0	5.4	31.0	23.5	81.0	64.0	12.2	1.4	14.6
26	0.0	6.3	33.5	24.5	86.0	56.0	12.4	6.9	21.8
27	0.0	5.4	31.5	23.5	90.0	64.0	17.8	2.9	16.6
28	18.0	7.9	28.5	22.0	95.0	97.0	13.8	0.0	9.0
29	4.6	3.3	28.5	23.2	93.0	89.0	11.7	0.9	9.1
30	0.0	3.4	30.0	24.0	84.0	74.0	14.2	2.3	12.5
MEAN	136.2	318.9	36.5	25.0	70.4	41.9	14.7	6.6	20.1

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DATA FOR THE MONTH..... 7 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	3.4	3.5	30.5	23.6	87.0	69.0	13.3	1.6	11.0
2	0.0	4.8	30.5	22.8	87.0	66.0	16.3	0.2	12.2
3	0.0	8.0	33.0	23.6	81.0	52.0	17.3	8.1	22.0
4	0.0	9.6	33.0	23.5	80.0	45.0	17.1	5.1	20.1
5	0.0	6.4	33.5	24.5	78.0	46.0	12.4	7.8	21.3
6	7.0	6.4	33.5	23.5	88.0	44.0	8.0	7.5	20.9
7	6.0	6.9	34.0	23.5	93.0	50.0	9.9	7.7	23.6
8	22.2	4.0	31.5	22.5	95.0	71.0	9.2	2.4	13.1
9	0.0	3.6	29.6	24.2	90.0	69.0	8.0	1.2	15.0
10	53.4	5.6	32.8	22.8	88.0	64.0	10.4	3.6	16.8
11	0.0	4.4	30.4	23.4	88.0	71.0	11.5	3.4	16.2
12	0.0	4.3	30.6	22.8	92.0	63.0	13.9	2.0	15.1
13	5.0	5.7	31.5	22.5	93.0	57.0	14.7	4.0	16.8
14	0.0	5.4	32.0	23.2	88.0	62.0	15.5	3.9	16.7
15	0.8	4.2	30.5	23.0	87.0	64.0	15.0	1.7	13.4
16	6.8	2.6	29.0	23.0	88.0	75.0	14.1	0.0	11.3
17	0.0	6.6	30.5	23.6	88.0	61.0	17.2	3.9	17.9
18	0.0	2.7	27.5	23.0	93.0	77.0	20.8	0.0	8.7
19	3.8	2.3	26.5	22.5	87.0	83.0	18.3	0.0	6.7
20	12.6	2.2	26.0	21.5	95.0	84.0	16.7	0.0	6.6
21	16.4	1.9	25.5	22.5	87.0	93.0	16.8	0.0	6.5
22	15.2	1.4	28.5	22.5	97.0	74.0	16.2	0.3	12.8
23	16.8	1.2	27.8	21.5	97.0	85.0	12.6	0.0	10.1
24	35.8	2.8	27.0	21.5	98.0	84.0	16.1	0.0	7.7
25	4.8	4.0	27.5	21.8	95.0	77.0	11.0	0.0	9.6
26	0.0	5.9	30.2	22.5	90.0	63.0	15.9	9.2	22.6
27	35.4	9.7	31.0	21.6	93.0	65.0	13.5	9.3	22.3
28	3.0	5.0	30.2	22.8	97.0	67.0	10.4	3.8	17.9
29	3.6	4.2	29.8	22.5	97.0	68.0	7.8	4.2	19.2
30	0.0	4.0	29.5	22.5	95.0	78.0	5.9	3.3	16.2
31	0.0	3.8	30.5	23.0	95.0	64.0	8.4	7.0	19.5
MEAN	252.0	143.1	30.1	22.8	90.5	67.5	13.4	3.3	15.2

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DATA FOR THE MONTH..... 8 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	5.0	30.0	22.5	90.0	67.0	10.3	5.4	17.0
2	0.0	5.3	31.0	23.5	87.0	66.0	14.0	7.0	20.0
3	2.0	5.7	30.0	22.5	91.0	61.0	17.1	1.8	16.9
4	5.0	5.9	30.0	22.4	92.0	71.0	14.7	3.9	17.8
5	0.0	4.0	30.0	22.5	88.0	76.0	11.3	5.0	16.5
6	0.0	5.7	31.6	23.0	82.0	56.0	10.7	9.9	22.3
7	0.0	5.0	32.0	23.2	84.0	52.0	10.0	8.9	22.6
8	10.0	7.5	31.0	22.6	90.0	55.0	16.2	5.7	17.8
9	0.0	4.9	29.6	22.6	85.0	63.0	14.2	1.0	15.4
10	4.4	4.4	31.0	22.8	93.0	61.0	9.8	5.9	17.7
11	0.0	3.2	30.0	23.0	95.0	69.0	5.0	0.6	12.4
12	11.8	3.8	31.0	23.0	95.0	82.0	4.7	5.0	12.9
13	30.0	4.0	31.5	22.5	93.0	60.0	11.4	7.3	20.4
14	0.0	6.0	27.8	22.0	91.0	61.0	13.1	9.7	22.3
15	0.0	7.2	30.5	22.5	81.0	65.0	12.2	11.3	23.8
16	0.0	6.3	31.0	22.8	87.0	54.0	11.4	10.1	23.4
17	0.0	5.0	30.0	23.5	90.0	62.0	7.5	6.7	19.4
18	0.0	4.8	31.5	22.5	91.0	58.0	8.2	7.4	21.1
19	0.0	5.4	30.5	24.2	89.0	66.0	6.9	3.7	18.3
20	63.0	1.8	31.0	21.2	98.0	63.0	8.1	3.9	18.0
21	1.8	3.8	29.5	23.2	93.0	72.0	6.4	3.8	17.5
22	18.0	9.9	30.5	23.0	98.0	65.0	7.4	8.4	21.2
23	29.2	2.5	30.5	22.0	95.0	72.0	5.6	6.4	17.4
24	0.0	4.7	30.5	24.5	95.0	72.0	6.7	5.6	21.1
25	0.0	4.9	31.0	23.5	92.0	66.0	6.6	7.1	20.7
26	0.0	5.3	32.0	23.5	93.0	61.0	8.2	6.2	21.5
27	2.2	3.6	30.2	23.4	92.0	82.0	8.0	2.4	13.4
28	3.6	3.8	29.5	22.6	95.0	67.0	9.9	1.0	13.5
29	32.4	3.3	30.0	22.0	98.0	67.0	11.1	0.0	15.2
30	31.6	1.6	24.6	22.2	98.0	97.0	8.3	3.5	5.4
31	0.6	2.4	26.5	22.2	95.0	84.0	16.2	0.0	9.3
MEAN	245.6	146.7	30.2	22.8	91.5	66.9	10.0	5.3	17.8

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DATA FOR THE MONTH..... 9 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	2.8	28.0	22.8	93.0	81.0	12.2	2.2	11.4
2	0.0	3.9	27.0	23.0	87.0	81.0	28.2	0.3	9.7
3	0.0	4.0	29.0	23.0	87.0	67.0	23.3	5.5	16.2
4	0.0	6.4	30.0	21.2	91.0	62.0	18.6	8.3	22.6
5	0.0	7.2	31.0	20.6	93.0	50.0	14.0	10.1	24.2
6	0.0	3.2	28.2	20.6	90.0	67.0	8.5	2.6	12.2
7	2.5	4.5	31.0	20.5	95.0	51.0	7.9	9.0	21.5
8	0.0	6.0	30.0	20.0	83.0	57.0	7.9	10.2	22.5
9	0.0	5.4	31.0	21.0	90.0	48.0	6.5	10.6	24.8
10	0.0	5.2	32.0	21.6	95.0	50.0	4.7	9.9	24.2
11	0.0	4.6	32.0	23.0	92.0	56.0	3.2	5.3	17.7
12	17.6	5.0	31.0	22.5	98.0	75.0	5.7	5.7	14.7
13	1.3	2.3	30.0	23.4	97.0	71.0	4.2	2.8	15.0
14	20.2	5.0	29.8	22.0	98.0	73.0	5.7	3.4	14.6
15	0.8	4.5	29.8	22.5	88.0	74.0	7.0	3.6	14.9
16	20.4	2.3	30.2	21.4	98.0	71.0	7.5	5.4	18.0
17	33.0	3.6	26.8	23.0	98.0	94.0	5.8	0.0	6.0
18	7.6	3.5	26.4	22.8	98.0	83.0	6.4	0.0	7.5
19	2.6	2.8	28.2	22.0	97.0	87.0	7.2	0.0	10.4
20	0.7	3.5	29.6	22.6	92.0	72.0	6.7	4.7	14.4
21	0.0	3.6	31.6	23.2	88.0	79.0	8.1	6.7	17.1
22	0.0	6.0	31.0	22.6	88.0	55.0	8.7	8.4	23.1
23	6.2	6.3	30.4	21.6	87.0	60.0	8.8	2.7	17.9
24	0.0	4.4	30.8	21.5	92.0	60.0	5.8	6.2	20.8
25	0.0	4.6	31.0	21.4	95.0	57.0	5.1	8.7	22.8
26	0.0	4.7	31.5	22.5	97.0	58.0	5.5	9.6	21.9
27	0.0	4.8	32.0	22.4	95.0	51.0	4.0	8.9	22.3
28	0.0	5.3	32.5	22.4	90.0	45.0	5.0	9.7	22.3
29	0.0	4.7	32.5	22.7	93.0	51.0	5.3	7.1	22.1
30	0.0	4.2	32.0	22.0	97.0	56.0	6.1	3.7	16.9
MEAN	112.9	134.3	30.2	22.1	92.7	64.7	8.5	5.7	17.7

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DATA FOR THE MONTH..... 10 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	2.4	30.0	21.0	97.0	70.0	2.5	2.8	6.0
2	6.5	4.6	31.5	22.6	92.0	63.0	4.2	8.1	19.1
3	0.0	4.5	31.5	21.0	92.0	89.0	2.2	6.2	16.7
4	0.0	5.2	33.0	21.0	93.0	46.0	3.0	9.7	22.6
5	0.0	5.2	32.8	19.2	95.0	43.0	4.9	9.8	21.7
6	0.0	6.4	33.2	19.4	95.0	37.0	5.5	10.0	22.8
7	0.0	5.6	32.5	19.5	95.0	44.0	5.6	8.9	20.7
8	0.0	4.8	31.6	19.2	83.0	35.0	4.6	1.2	13.5
9	11.0	6.6	32.0	22.2	98.0	37.0	9.5	4.0	17.9
10	51.0	4.5	27.5	22.0	98.0	92.0	4.0	0.0	8.2
11	14.0	5.1	26.5	22.5	98.0	80.0	6.4	0.2	7.5
12	14.6	4.9	28.5	22.0	98.0	78.0	3.5	1.2	9.5
13	0.0	1.8	27.6	21.5	98.0	74.0	3.3	0.3	11.4
14	0.0	3.4	30.2	22.2	97.0	63.0	2.9	4.5	16.8
15	59.0	3.8	29.5	20.5	98.0	85.0	3.8	1.1	9.0
16	33.4	4.1	28.0	20.5	98.0	97.0	5.8	2.5	9.4
17	50.0	3.5	25.8	21.8	98.0	89.0	6.3	0.0	6.9
18	64.0	1.4	26.0	21.5	98.0	98.0	8.2	0.0	2.6
19	46.2	3.0	25.0	22.0	97.0	98.0	15.4	0.0	3.8
20	4.0	2.1	26.0	20.2	98.0	90.0	14.4	2.2	11.6
21	1.0	3.0	24.6	21.5	96.0	98.0	7.7	1.1	6.1
22	0.0	2.0	25.0	21.0	97.0	92.0	3.9	1.0	9.8
23	5.0	1.6	27.5	20.5	96.0	79.0	3.1	2.8	11.0
24	0.0	2.8	29.5	21.5	97.0	71.0	5.2	6.9	16.0
25	1.3	3.4	29.0	20.0	95.0	82.0	6.4	6.9	16.2
26	0.0	4.0	29.0	18.5	91.0	64.0	5.6	9.0	17.7
27	0.0	4.7	30.0	17.6	94.0	46.0	4.2	10.5	20.7
28	0.0	5.2	29.5	17.0	91.0	48.0	5.2	10.6	21.0
29	0.0	4.0	29.5	18.0	93.0	57.0	4.2	9.0	18.6
30	0.0	3.9	30.0	18.0	98.0	59.0	3.5	10.0	20.4
31	0.0	4.6	30.0	17.2	94.0	48.0	4.3	10.1	20.3
MEAN	361.0	122.1	29.1	20.4	95.4	69.4	5.5	4.9	14.0

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DATA FOR THE MONTH..... 11 YEAR...... 1995

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	4.6	29.5	17.0	98.0	47.0	4.6	10.2	20.9
2	0.0	4.4	30.0	16.5	98.0	47.0	6.1	10.2	19.7
3	0.0	5.7	30.0	15.0	94.0	40.0	5.7	10.4	20.2
4	0.0	5.4	29.5	14.2	90.0	35.0	6.0	10.8	20.6
5	0.0	4.1	30.0	14.5	90.0	47.0	4.3	10.3	20.3
6	0.0	4.5	28.5	14.5	94.0	45.0	4.1	10.7	20.5
7	0.0	5.2	29.0	13.5	90.0	45.0	4.7	10.3	20.3
8	0.0	5.6	28.0	13.5	94.0	37.0	5.6	10.4	20.6
9	0.0	4.1	30.0	19.0	93.0	43.0	6.5	9.5	19.8
10	0.0	5.0	29.6	15.0	89.0	50.0	8.1	10.6	19.9
11	0.0	3.7	31.0	18.0	93.0	45.0	4.3	10.3	17.8
12	0.0	4.5	31.2	22.2	91.0	50.0	7.3	8.1	17.2
13	0.0	5.5	30.5	16.0	90.0	40.0	5.3	10.3	19.1
14	0.0	5.5	30.0	15.2	85.0	38.0	5.4	10.5	19.7
15	0.0	5.9	29.0	11.4	85.0	28.0	6.2	10.4	19.6
16	0.0	5.0	28.8	11.5	96.0	26.0	5.2	10.4	20.1
17	0.0	5.0	28.8	14.2	90.0	29.0	4.9	10.4	19.9
18	0.0	3.2	28.8	17.0	94.0	51.0	3.3	7.6	14.7
19	0.0	3.9	28.8	18.8	96.0	55.0	5.2	7.2	13.0
20	0.0	4.0	29.0	16.5	96.0	47.0	5.6	9.7	16.4
21	0.0	5.6	29.0	16.5	94.0	48.0	7.0	9.3	16.6
22	0.0	3.8	30.0	18.8	96.0	47.0	6.2	9.8	18.0
23	0.0	4.7	29.5	19.5	93.0	51.0	6.4	9.3	15.9
24	13.0	3.5	29.0	20.0	93.0	74.0	8.6	7.6	15.4
25	0.0	3.8	28.2	16.2	87.0	61.0	5.2	6.3	15.3
26	0.0	3.1	27.0	16.8	88.0	45.0	4.2	9.3	17.1
27	0.0	5.0	29.0	14.5	90.0	31.0	5.7	10.1	18.7
28	0.0	4.8	29.0	16.5	96.0	41.0	8.2	9.3	17.6
29	0.0	5.0	29.0	16.5	87.0	47.0	9.0	6.5	15.3
30	0.0	4.1	29.5	16.5	96.0	38.0	6.9	7.1	16.5
MEAN	13.0	138.2	29.3	16.2	92.2	44.3	5.9	9.4	18.2

PLEASE NOTE THAT RAINFALL AND EVAPORATION DATA ARE TOTALS,NOT MEANS
PLEASE NOTE THAT -99.9 STANDS FOR DATA NOT YET ENTERED

[illegible]

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	4.8	29.5	17.5	91.0	47.0	7.1	8.8	16.3
2	0.0	4.8	29.0	16.2	96.0	47.0	7.1	8.8	16.3
3	0.0	4.0	28.6	17.0	91.0	45.0	4.4	8.6	16.5
4	0.0	4.0	29.5	17.0	96.0	45.0	4.4	8.6	14.2
5	0.0	3.0	29.0	16.0	98.0	49.0	3.1	8.9	15.1
6	0.0	3.5	30.0	17.0	98.0	44.0	3.0	8.6	15.7
7	0.0	4.9	28.5	12.8	87.0	47.0	5.1	8.7	14.8
8	0.0	5.4	28.0	11.2	89.0	29.0	6.1	10.5	18.2
9	0.0	4.8	27.0	11.0	89.0	36.0	6.5	10.1	17.8
10	0.0	3.9	27.5	12.5	90.0	31.0	4.5	10.5	17.5
11	0.0	4.0	28.5	12.5	96.0	25.0	5.1	9.6	17.2
12	0.0	4.5	27.5	11.4	98.0	42.0	5.9	9.9	16.9
13	0.0	3.7	28.5	11.2	98.0	32.0	4.2	10.2	17.4
14	0.0	4.2	28.5	13.0	96.0	34.0	4.7	10.0	17.5
15	0.0	4.2	29.0	13.0	93.0	32.0	5.1	10.1	17.1
16	0.0	4.6	29.5	13.2	92.0	29.0	5.1	10.1	17.3
17	0.0	4.2	29.0	12.5	96.0	36.0	6.0	9.9	16.7
18	0.0	3.8	29.0	13.4	98.0	33.0	5.4	9.7	16.7
19	0.0	4.5	29.0	12.5	98.0	43.0	5.5	10.0	17.2
20	0.0	5.0	29.0	9.8	95.0	30.0	3.3	10.0	17.8
21	0.0	4.3	28.5	12.0	98.0	37.0	6.5	10.0	17.5
22	0.0	3.8	28.5	14.0	98.0	43.0	6.5	10.0	16.7
23	0.0	4.0	28.8	13.5	96.0	37.0	5.9	10.1	17.2
24	0.0	4.8	29.2	13.8	98.0	33.0	7.5	10.5	17.6
25	0.0	4.7	28.8	15.8	96.0	27.0	10.6	9.9	18.4
26	0.0	3.7	27.0	17.2	94.0	50.0	8.8	10.0	15.5
27	0.0	4.8	26.8	14.2	81.0	45.0	9.2	10.0	17.5
28	0.0	4.6	27.2	16.4	96.0	42.0	9.5	9.4	17.2
29	0.0	3.5	26.5	14.5	93.0	52.0	8.2	8.8	13.9
30	0.0	3.3	26.0	14.5	96.0	54.0	7.1	8.4	13.0
31	0.0	3.9	27.5	15.5	94.0	42.0	8.5	9.6	16.1
MEAN	0.0	131.2	28.4	13.9	94.4	39.3	6.1	9.6	16.6

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[illegible]

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	4.6	28.0	15.5	90.0	35.0	11.6	10.5	17.5
2	0.0	4.7	27.5	15.4	94.0	37.0	11.1	9.8	17.9
3	0.0	5.2	27.5	15.5	88.0	36.0	11.6	10.2	17.6
4	0.0	4.9	27.5	15.0	96.0	34.0	8.8	10.4	18.0
5	0.0	4.8	27.5	13.5	75.0	39.0	8.8	10.4	17.7
6	0.0	6.0	28.5	16.5	92.0	34.0	13.7	10.1	17.6
7	0.0	5.0	28.5	15.5	88.0	38.0	10.6	10.6	17.6
8	0.0	5.8	30.0	13.5	96.0	25.0	8.6	9.9	17.2
9	0.0	4.7	29.5	13.2	94.0	33.0	7.4	10.3	17.8
10	0.0	4.8	28.5	15.5	96.0	41.0	8.5	9.3	16.1
11	0.0	4.1	28.8	14.5	98.0	35.0	7.3	9.6	16.7
12	0.0	4.4	30.0	17.5	91.0	33.0	6.9	7.9	15.9
13	0.0	4.6	30.0	15.2	81.0	35.0	9.4	8.1	16.6
14	0.0	5.6	30.2	16.5	81.0	28.0	11.1	10.4	17.8
15	0.0	5.6	29.6	16.5	94.0	30.0	10.8	10.4	17.9
16	0.0	5.3	29.5	18.5	96.0	40.0	11.1	10.0	17.6
17	0.0	3.6	29.5	17.8	94.0	47.0	7.0	7.9	14.3
18	0.0	2.6	30.0	17.0	94.0	50.0	3.4	7.2	12.0
19	0.0	5.0	31.6	17.5	94.0	30.0	5.6	9.0	16.9
20	0.0	6.0	32.0	15.2	98.0	22.0	7.1	10.3	18.1
21	0.0	4.2	30.5	15.0	92.0	36.0	3.4	10.1	17.5
22	0.0	4.2	30.5	16.4	90.0	34.0	5.0	8.9	16.5
23	0.0	5.8	29.5	15.0	92.0	41.0	6.3	10.0	17.0
24	0.0	6.0	29.5	14.0	85.0	31.0	7.1	10.7	18.2
25	0.0	6.0	29.0	12.0	95.0	32.0	6.8	10.3	18.6
26	0.0	5.8	30.2	14.0	84.0	41.0	4.8	10.5	18.9
27	0.0	5.0	31.0	14.5	90.0	28.0	5.3	10.0	17.4
28	0.0	6.4	30.5	16.2	75.0	30.0	7.9	10.5	18.1
29	0.0	6.2	30.0	15.0	96.0	37.0	8.1	10.5	18.8
30	0.0	5.6	30.8	15.2	88.0	34.0	7.8	10.4	18.4
31	0.0	6.0	30.8	15.6	88.0	29.0	6.8	10.3	18.3
MEAN	0.0	158.5	29.6	15.4	90.5	34.7	8.1	9.8	17.3

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DATA FOR THE MONTH..... 2 YEAR...... 1996

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	5.6	31.0	16.0	86.0	31.0	6.5	8.0	14.7
2	0.0	5.7	31.2	17.2	87.0	34.0	7.9	9.5	17.5
3	0.0	6.5	29.5	14.8	94.0	44.0	8.4	9.9	16.9
4	0.0	6.4	30.0	15.6	87.0	34.0	7.9	10.2	18.2
5	0.0	6.4	30.0	15.0	84.0	40.0	8.1	9.9	18.3
6	0.0	6.4	30.5	14.5	90.0	33.0	6.7	10.0	17.9
7	0.0	6.8	30.5	13.0	87.0	29.0	7.0	10.2	18.6
8	0.0	6.8	29.8	16.0	90.0	29.0	8.1	10.4	19.0
9	0.0	7.2	29.5	15.0	80.0	27.0	12.8	10.2	18.4
10	0.0	6.0	28.5	19.0	93.0	23.0	14.2	10.4	19.6
11	0.0	6.0	30.0	16.0	96.0	35.0	9.4	7.3	14.8
12	0.0	4.0	28.5	16.8	94.0	50.0	7.8	8.3	16.0
13	0.0	4.4	28.5	17.0	94.0	49.0	8.4	7.9	14.6
14	0.0	4.9	29.6	17.0	96.0	47.0	7.4	8.5	15.2
15	0.0	5.4	30.0	18.0	87.0	45.0	9.2	8.5	16.6
16	0.0	6.2	30.0	21.5	81.0	42.0	9.5	7.1	16.2
17	0.0	6.0	30.5	17.0	94.0	37.0	8.9	9.4	19.4
18	0.0	7.2	31.0	15.5	90.0	38.0	7.4	10.1	20.8
19	0.0	8.2	31.5	15.2	83.0	29.0	6.9	10.0	21.7
20	0.0	6.9	33.0	15.6	92.0	30.0	6.3	10.2	21.8
21	0.0	6.7	34.0	17.0	71.0	26.0	6.4	10.6	21.5
22	0.0	7.3	35.0	16.4	94.0	18.0	6.1	10.3	21.2
23	0.0	6.2	34.8	20.5	91.0	19.0	4.9	9.3	21.3
24	0.0	7.0	36.0	19.4	88.0	19.0	7.7	10.1	21.5
25	0.0	7.0	35.0	19.6	86.0	34.0	9.6	10.0	20.7
26	0.0	9.2	34.0	17.5	80.0	23.0	11.5	10.7	22.1
27	0.0	8.0	34.0	18.0	91.0	29.0	10.7	10.6	22.1
28	0.0	8.0	31.5	18.0	62.0	34.0	10.7	11.0	22.8
29	0.0	10.4	33.5	15.0	75.0	17.0	11.5	11.2	24.3
MEAN	0.0	192.8	31.4	16.8	87.0	32.6	8.5	9.6	19.1

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DATA FOR THE MONTH..... 3 YEAR...... 1996

DAY	RAIN mm	EVAP mm	TMAX C	TMIN C	RH07 %	RH14 %	WIND kphr	SUNSHINE hr	SOLRAD (MJ/m**2/D)
1	0.0	9.4	34.0	15.0	86.0	19.0	9.9	11.0	24.3
2	0.0	8.5	33.5	17.5	70.0	32.0	8.1	9.9	22.0
3	0.0	9.0	33.5	18.5	57.0	25.0	10.6	10.3	21.6
4	0.0	9.0	32.0	15.5	80.0	38.0	9.6	9.7	22.1
5	0.0	6.4	31.5	17.0	90.0	40.0	6.0	10.5	22.3
6	0.0	8.0	32.5	15.6	81.0	32.0	7.5	10.6	23.4
7	0.0	7.6	33.2	16.0	74.0	37.0	6.6	10.4	22.9
8	0.0	8.0	33.8	16.0	58.0	14.0	6.4	10.0	22.7
9	0.0	6.6	34.8	17.6	68.0	20.0	5.5	9.8	22.0
10	0.0	8.0	35.5	17.5	82.0	20.0	5.4	10.0	21.9
11	0.0	9.0	35.0	19.0	61.0	24.0	7.4	9.9	21.8
12	0.0	8.5	35.5	19.0	58.0	20.0	6.4	10.4	22.0
13	0.0	9.0	36.8	20.7	62.0	18.0	6.8	10.3	22.3
14	0.0	9.0	37.5	20.0	57.0	21.0	6.3	9.8	21.1
15	0.0	9.3	37.0	21.0	63.0	19.0	6.9	9.5	21.0
16	0.0	11.0	37.5	19.5	45.0	17.0	11.5	9.9	21.8
17	0.0	9.2	36.5	19.5	49.0	19.0	8.6	10.6	22.6
18	0.0	10.6	37.0	17.5	59.0	10.0	9.9	10.4	24.3
19	0.0	6.7	35.0	17.2	77.0	21.0	6.3	4.8	18.1
20	0.0	6.0	33.5	19.5	64.0	30.0	5.2	2.0	14.7
21	0.0	8.6	37.0	22.5	68.0	24.0	7.4	9.0	21.7
22	0.0	9.4	37.0	20.5	52.0	19.0	9.1	10.0	22.5
23	0.0	8.7	37.0	19.8	60.0	17.0	7.4	9.4	21.9
24	0.0	7.4	38.0	20.6	72.0	18.0	6.5	9.4	21.3
25	0.0	7.6	37.5	20.5	70.0	21.0	4.0	9.5	21.1
26	0.0	8.0	39.0	21.5	58.0	18.0	6.9	9.5	21.5
27	0.0	9.8	39.5	22.0	74.0	17.0	8.3	10.5	23.1
28	0.0	10.6	39.0	20.0	53.0	11.0	7.1	10.9	24.8
29	0.0	8.0	39.0	22.0	51.0	20.0	6.6	10.7	24.4
30	0.0	10.0	39.5	25.0	71.0	19.0	6.7	10.5	23.2
31	0.0	8.6	39.0	25.2	82.0	27.0	8.5	8.3	20.3
MEAN	0.0	265.5	36.0	19.3	66.2	22.2	7.4	9.6	22.0

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