# COMPARATIVE SUITABILITY OF DIFFERENT SYSTEMS OF CROPPING IN AN ARSENIC AFFECTED AREA



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*By*

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# CERTIFICATE

This is to certify that the work recorded in the thesis entitled **"COMPARATIVE SUITABILITY OF DIFFERENT SYSTEMS OF CROPPING IN AN ARSENIC AFFECTED AREA"** submitted by **Shri Samik Kumar Adak** in partial fulfilment of the requirements for the award of the Degree of **Doctor of Philosophy** in **Agronomy**, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, is a faithful and bonafide research work carried out under my personal supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received from various sources during the course of investigation have been duly acknowledged.

24.6.2002

**(B. K. Mandal)**
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# APPROVAL OF EXAMINERS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY

We, the undersigned, having been satisfied with the performance of **Shri Samik Kumar Adak** in the viva-voce examination, conducted today, the 4th october, 2002 recommended that the thesis be accepted for the award of the Degree.

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*Dedicated to my beloved*

*Parents,*

*Mr. Sunil Kumar Adak*

*&*

*Mrs. Kanan Adak*

*Sisters,*

*Ms. Sucharita and Suchismita*

*& Brothers*

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Dated, Mohanpur
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Samik Kumar Adak

(SAMIK KUMAR ADAK)

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| % | : Percentage |
| & | : And |
| @ | : At the rate of |
| $^0C$ | : Degree centigrade |
| CD | : Critical difference |
| cm | : Centimeter |
| DAS | : Days after sowing |
| DAT | : Days after transplanting |
| *et al.* | : And others |
| Fig. | : Figure |
| g | : Gram |
| $g^{-1}$ | : Per gram |
| $g\ m^{-2}$ | : Gram per square meter |
| ha | : Hectare |
| $ha^{-1}$ | : Per hectare |
| i.e. | : That is |
| m | : Meter |
| $m^{-2}$ | : Per square meter |
| Mg | : Milligram |
| N | : Nitrogen |
| P | : Phosphorus |
| K | : Potassium |
| NS | : Not significant |
| SEm | : Standard error mean |
| t | : Tonne |
| HYV | : High yielding variety |
| AAS | : Atomic Absorption Spectrophotometer |
| HG | : Hydride Generator |
| DTW | : Deep tube well |
| $d^{-1}$ | : Per day |
| ppm | : Parts per million |
| LAI | : Leaf area index |
| DM | : Dry matter |
| CGR | : Crop growth rate |

# ABSTRACT


The widespread arsenic (As) contamination in groundwater, at concentrations exceeding the maximum acceptable limit (0.05 mg As $l^{-1}$ of water), was first detected during 1978 in West Bengal, India, while in 1983 the first case of arsenic poisoning of a human being was diagnosed. Since then, it has spread over 68 blocks in 9 districts of the state.

Soil acts as the major sink of arsenic input to the environment, either through the natural processes or through the use of contaminated groundwater for irrigation. Soil serves as an important medium for accumulation, transformation and migration of such arsenic input. In this context, a thorough understanding of soil-arsenic interactions is important in order to judge as to how well such a sink be able to contain the toxin and prevent it from entering the food chain through plant uptake and leaching to surface run-off as well as in groundwater; besides, to examine the possibility of it's bio-magnification as it moves up the food chain.

Rice – rice system is, by far, the most predominant one in the arsenic affected areas of West Bengal. Furthermore, summer rice requires a huge quantity of water for the completion of it's growth. The above mentioned factor led to an unlimited use of groundwater mainly from the intermediate aquifer which seemed to be primarily responsible for arsenic mobilisation in groundwater and simultaneously acted as an input to soil arsenic contamination. The build-up of arsenic in soil might prove detrimental to plants through it's uptake thereby entering the food chain. The possibility of bio-magnification in course of travel of the toxin up in the food chain is also of great concern.

Under the above circumstances, there was a need to develop an appropriate crop cafeteria with crops having low water demand and high market value. With the above idea in view, an investigation on various systems of cropping, with crops having low water demand as well as high market value was undertaken in the arsenic affected areas of Gotera Mouza, Chakdah, Nadia, West Bengal, during March 1998 to June 2001 keeping in mind the objective to study the build-up or uptake of arsenic in

various plant parts including the consumable part as well as the change in soil build-up of arsenic by way of continued cultivation with water containing arsenic as well as to find out some suitable systems of cropping in respect of high net return, benefit : cost ratio and less water use to replace the traditional rice-rice system.

Altogether, ten crop sequences were tried including the traditional one, *i.e.*, rice (summer) – rice (winter) system as control in the farmers' fields which consisted of : maize – greengram – potato, elephant - foot yam – maize – greengram, elephant - foot yam – mustard – sesame, olitorius jute – greengram – potato – sesame, olitorius jute – rice – rice, elephant - foot yam – wheat – groundnut, greengram – rice – mustard, green manure – rice – rice, maize intercropped with greengram – greengram – potato and elephant - foot yam intercropped with cowpea – maize – greengram. The soil had an arsenic content of 1.23 – 1.37 mg $kg^{-1}$ of soil at the beginning of the experiment while the irrigation water had an arsenic content of 0.22 – 0.23 mg As $l^{-1}$ of water. The different crops were grown adopting their normal cultivation practices with cultivars best suited in the locality.

No visual phytotoxic effect of arsenic was observed on any of the studied crop plants and the plant growth remained unaffected as well as root growth exhibited no abnormality as evident from growth attributes like LAI, CGR, DM accumulation, etc.

Yield of different crops in various crop sequences over three years of experimentation were recorded. The yield data showed progressive increase over the years. The newly introduced crops like elephant - foot yam, groundnut, etc. recorded satisfactory yields.

By and large, arsenic content in different plant parts declined progressively in most of the studied crops from root to stem, to leaf and to economic produce. Plants showed build-up of arsenic in increasing amount with the progress of growth, attaining the highest value at harvest, although it's magnitude varied among the different crops.

Sesame recorded the lowest arsenic content (0.40 mg $kg^{-1}$) in the seeds at 30 DBH in 1$^{st}$ year while wheat roots recorded maximum uptake of 14.00 mg As $kg^{-1}$ at harvest in 3$^{rd}$ year among all the crops tested.

With regard to the consumable portion (above ground) of the crops, grains of summer rice (dehusked) recorded the maximum uptake (10.00 mg $kg^{-1}$) during both $2^{nd}$ and $3^{rd}$ years, at harvest. Different plant parts of summer rice exhibited higher values of uptake as compared to the corresponding winter rice during all the 3 years of experimentation. Among the crops, the highest uptake was noted in wheat roots while the lowest value was found in the seeds of sesame. Crops like elephant-foot yam, greengram, maize, groundnut, etc. showed moderate uptake of arsenic in the economic produces. The alarming point was that all the crops showed progressively increasing values of arsenic concentration in different plant parts at unequal proportions over the years.

Among the crops tried during the lean months (*i.e.,* in summer season), summer rice recorded the highest values of arsenic concentration in different plant parts. The oilseed crops showed lower values of arsenic concentration in the seeds, *i.e.,* in the consumable portions compared with the cereals. In case of elephant-foot yam and potato, however, the economic portions in spite of being underground, recorded arsenic build-up to a less extent.

Soils showed progressive build-up of arsenic with continued cultivation using irrigation water loaded with arsenic. It showed increasing trend of arsenic in soils gradually beginning with post-monsoon to ***rabi*** season and attaining the peak value before monsoon, *i.e.,* during the summer months, while it showed declining trend during the monsoon or just after the cessation of monsoon in various cropping sequences. Although there was some decline in soil arsenic values during the monsoon months, nevertheless, it increased unequally in different crop sequences in any single year. All the cropping sequences tried showed increase (in unequal proportions) in available arsenic content of soil at the end of three years of cropping. Final contents varied from 1.69 to 3.10 mg As $kg^{-1}$ of soil from an initial value of 1.20 – 1.37 mg $kg^{-1}$ with different systems of cropping. Crops like greengram, groundnut, incorporation of green manure, wheat, etc. showed lowering of soil arsenic content after their harvest while elephant-foot yam, maize, potato, jute, summer rice, etc. showed increase in values after their harvest. *Boro* or summer rice exhibited the greatest increase in soil available arsenic content among all the crops tried while in *aman* or winter rice both increase as well as decline was seen in soil available arsenic content after it's cultivation.

Soil fertility, in respect of N, showed improvement in most of the sequences tried at the end of third year of cropping. Available P contents of soil registered an improvement in all the sequences tried at the end while available K contents of soil showed both increase as well as decrease towards the end.

The highest benefit : cost ratios of 2.13 : 1 and 2.14 : 1 were obtained in greengram - rice (winter) – mustard sequence during 2nd and 3rd year of investigation, respectively, followed by elephant-foot yam – mustard - sesame having the benefit : cost ratio of 1.95 : 1 and 2.03 : 1. Sequences, namely, elephant-foot yam – maize – greengram, elephant-foot yam – mustard – sesame, olitorius jute – greengram – potato – sesame recorded equal or higher benefit : cost ratio as compared to the traditional one, *i.e.*, rice – rice system.

It was also noted that greengram – rice –mustard sequence was associated with the lowest requirement of water throughout the year but gross return and corresponding benefit : cost ratio was higher when compared with the volume of water given to other sequences through irrigation. Most of the sequences showed similar trend of low volume of water need alongwith high return in comparison with the traditional rice – rice sequence requiring the highest amount of water.

Therefore, crop sequences having low water need throughout the year as well as economically sound can suitably be raised to replace the high water responsive rice-rice sequence with a view to reduce the pressure on groundwater withdrawal for irrigation to prevent the further spread of such arsenic contamination. Sequences like elephant-foot yam – mustard – sesame, elephant-foot yam - maize - greengram, greengram – rice – mustard, etc. can suitably be grown as substitute of rice – rice sequence. Crops like sesame, mustard, greengram, etc. are found to contain less arsenic in the plant parts as well as having low water need can suitably be grown (especially during the summer or lean months) as substitute of summer rice which can also keep the soil build-up of arsenic to a lower value.

# Chapter 1

# INTRODUCTION

# 1. INTRODUCTION

Since independence, Indian agriculture has made rapid strides. In 1999-2000 India has produced nearly 206 m t of foodgrains from 142 m ha of cultivated land as compared to only 50 m t in the early fifties following the way of green revolution. The irrigated areas account for 37 % of crop land and contribute about 55 % of food production.

The so called 'Green Revolution' of the sixties witnessed impressive gains in foodgrain production due to the release of high yielding varieties (rice, wheat, maize, jowar and bajra) in India, adapted to intensive agriculture. It sailed us to become self-sufficient in food grain production; on the contrary, it promoted the use of fertilizers (mainly inorganic), pesticides and heavy exploitation of groundwater resource for irrigation. On ecological grounds, numerous critics have questioned on the sustainability of the green revolution, (decrease fallow periods between the crops etc.), which led to water logging, salinisation, and other problems associated with expansion of irrigation, increased run-off and soil erosion. To have a stable productivity, HYVs called for an increased use of fertilizers and irrigation – both, in turn, have become a source of soil and water pollution in a way or other.

Pollution means the presence of undesirable substances in any segment of the environment, primarily due to human activity, discharging by-products, waste products or harmful secondary products, which are harmful to man and other organisms. However, it should be borne in mind that, even in natural state, no environmental components is pure in the scientific sense, having several admixtures and impurities. The quality of our environment has been constantly degrading and the stocks of non-renewable resources are decreasing at a very alarming rate. With this pace of exploitation of renewable natural resources, extinction of wild life, loss of gene pool, pouring of toxic chemicals including many non-biodegradable ones in soil, water and air, it would be impossible for humanity to survive for long. The survival of different plant and animal texa depend upon their genetic make up and the ability to adjust to the prevailing and gradual or sudden changes of the total environmental complex *vis-à-vis* to competitions. The survival of man depend on how judiciously he manages the earth and maintains the quality of his overall environment. We cannot change to adapt to fast changing and pollutive environment such as rise of $CO_2$ in the atmosphere or to reduced $O_2$ content in the air we breath or to water containing toxic levels of various organic and inorganic substances. We cannot develop resistance to toxic effects of several kinds of poisonous materials which are thrown in the atmosphere, waterbodies and soils. These poisonous materials reach to our body through the air we breath, the water we drink and the food we eat. We are reaching to the limits of tolerance on most fronts and any greater onslaught would give rise to mass scale sudden death or disease, disablement and crippling, and slow death of people in various parts of the world. Man has, by now, no option but to seriously fight for the cause of sustained quality of his environment and natural resources.

Aquatic or water pollution refers to a situation wherein the water quality deteriorates and becomes harmful to man, his domestic needs or other aquatic life or to a balanced functioning of the aquatic ecosystem. The physical aspects of water pollution may be in the form of change in: (i) the colour of water, (ii) the odour due to several factors leading to foul smell unfit for drinking, (iii) temperature which may be harmful directly as a primary pollutant and indirectly through driving out of dissolved $O_2$, (iv) turbidity which reduces light and dissolved oxygen and (v) density of water which changes with the change in temperature and causes upturning of water. The causes of chemical aquatic pollution are of numerous types, e.g., the dissolved solids, hardness of water, pH change, dissolved oxygen ($O_2$), carbon dioxide ($CO_2$), metallic ions, namely, iron, copper, **Arsenic (As)**, lead, mercury, etc.

The presence of arsenic in groundwater at concentrations exceeding the maximum acceptable concentration, MAC (0.05 mg $l^{-1}$), was first detected in 1978, while in 1983 the first case of arsenic poisoning of a human being was diagnosed at the School of Tropical Medicine in Kolkata (Acharya, 1997). Groundwater contamination with arsenic has been reported from Argentina, Canada (Ontario), USA (Arizona, California, Washington, etc.), Chile (Antofagasta), Mexico, Poland, Greece, etc. and several other countries. In Asia, West Bengal (India) has the highest number of people who consume arsenic-contaminated water and suffer from arsenicosis followed by China where more than 2,50,000 people are exposed to arsenic poisoning (The Statesman, 1st December, 1996). Within a short period, after the first arsenic poisoning was detected in West Bengal, over 68 blocks in 8 districts of the state has been reported to yield arsenic contaminated water and about 5 to 6 m people have been exposed to, rather forced to, drink water with different degrees of arsenic contamination and more than 2,00,000 people suffer from arsenic poisoning related diseases. Mandal *et al.* (1996) first reported it and termed it as the 'biggest arsenic calamity in the world' considering the sheer magnitude of such an environmental hazard.

Arsenic content in groundwater beyond the permissible limit (0.05 mg $l^{-1}$) has been found in parts of the districts of Malda, Murshidabad, Nadia, North and South 24-Parganas lying in the eastern bank of the Ganga-Bhagirathi basin and in Burdwan district along the western bank of Bhagirathi (Sinha Ray, 1995). Mandal *et al.* (1996) gave a survey report of the arsenic affected blocks and villages in the state [Table A(i) & A(ii) in the appendix] and arsenic concentration in groundwater and arsenic content in hair, nail, urine and skin-scale of people drinking arsenic-contaminated water above 0.05 mg $l^{-1}$ [Table A(iii) in the appendix].

The two biggest cases of groundwater arsenic contamination in Bangladesh and West Bengal (India) have been reported by Chowdhury *et al.* (1999) based on data emerging from 10-year survey conducted in the affected areas. Sixty four districts of Bangladesh and 9 districts of West Bengal are reported to be arsenic contaminated affecting nearly 100 m people.

The Steering Committee, set up by the Government of West Bengal, composed of relevant Departments/Agencies of the Central and State Governments, as well as the NGOs, carried out the first comprehensive study of the problem from 1988 to 1991 (PHED, 1991). The Geological Survey of India (GSI) also carried out investigations in selected areas of the affected districts in 1988-90 and again in 1992-96.

The seriousness of the problem assumed such a magnitude that an epidemiology team from the University of Berkley, California, sent by World Health Organisation (WHO) to Bangladesh where a similar problem existed found "the largest mass poisoning of a population in history .... on a scale greater than Bhopal and Chernobyl". The source of the problem in both West Bengal and Bangladesh is reported to be alike: the digging of deep tube wells which brings arsenic in geological deposits underground.

The problem is much more serious than unusally one can imagine, as well as it is gradually aggravating. Very few people are, in fact, aware about this problem. Arsenic is a metalocid which is placed in group V and period 4 of the periodic table and is highly mobile under neutral to slightly alkaline conditions. One of the earliest reference to the use of arsenic (around 3000 BC) was found in Bronze alloys (Partington, 1935). Arsenic is also reported to be used in medicines well before 400 BC. It's wide use in agriculture may possibly be traced to the introduction in 1868 in USA of Paris Green (copper acetoarsenite) as an insecticide to control potato beetle. Calcium, lead, magnesium and zinc arsenates, zinc arsenite and Paris Green have also been used as insecticides in orchards since the early $19^{th}$ Century to 1960s (Woolson *et al.,* 1971a). At present, arsenic acid ($H_3A_sO_4$), sodium arsenite and arsenate ($NaAsO_2$ and $Na_3AsO_4$) and dimethyl arsinic acid, DMA [$(CH_3)_2$ AsO (OH)], are being used as defoliants while disodium methano arsonate, DSMA [$CH_3$ AsO ($O^-$ $Na^+)_2$], monosodium methano arsonate, MSMA [$CH_3AsO(OH)$ ($O^-Na^+$)], and methyl arsonic acid, MAA [$CH_3AsO(OH)_2$] are being used since mid-70s as herbicides (Onken and Hossner, 1996). Organic arsenicals have also been used as silvicides and dessicants (Levander, 1977). Apart from it's use in agriculture, arsenic compounds have been used in several industrial applications in alloys, automotive body solder, electrophotography, etc. arsanilic acid is used in feed additives; arsenic trioxide and arsenic salts are used as soil sterilizers, while phenyl arsenic compounds have been found to be used in animal feed additives and disease prevention (Nriagu and Azcue, 1990).

Environmental contamination with arsenic has primarily been reported to be due to several anthropogenic activities such as mining operations, industries, agriculture and manufacturing. The application of arsenicals as herbicides and pesticides has contributed to contamination in course of its transportation, distribution, storage and above all through the building-up of residual arsenic in soil-plant system. A considerable amount of arsenic is being emitted during smelting of base metal ores. Coal combustion also contributes to it.

The recommended safe limit is 0.01 mg $l^{-1}$ while the maximum permissible limit or maximum acceptable concentration (MAC) of arsenic is 0.05 mg $l^{-1}$ of water (WHO, 1993).

The toxicity of arsenic compounds depends largely on the oxidation state and whether arsenic is present in organic combinations. The toxicity follows the order: arsine (valence or oxidation state of arsenic: -3) > organo-arsine compounds > arsenites (+3) and oxides (+3) arsenates (+5) > arsonium metals (+1) > elemental arsenic (0).

Arsenic is extremely toxic to human - as small as 0.1 g of arsenic trioxide can prove to be lethal to human being. The said toxicity to human beings depends largely on the concentration and the duration or length of exposure. Toxicity usually develops after six months to two years or more depending on the amount of intake of arsenic laden groundwater and the concentration of arsenic in it. Early symptoms of arsenic poisoning includes skin lesions, weakness, langour, anorexia, nausea and vomitting with diarrhoea or constipation. With the progress of poisoning, the symptoms attain more characteristic features which include acute diarrhoea, edema, skin pigmentation, arsenical melanosis and hyperkeratosis, enlargement of liver, respiratory diseases and skin cancer.

Dissolved arsenic concentrations in natural waters (except groundwater) are generally low, being < 0.002 to 0.59 $\mu g\ l^{-1}$ in rain water and snows, 0.20 to 264 $\mu g\ l^{-1}$ in rivers, and 0.15 to 6.0 $\mu g\ l^{-1}$ in seas (Welch *et al.,* 1988). Various anthropogenic activities such as emissions from smelters have led to elevated levels of arsenic in precipitation which, in turn, has caused high arsenic concentrations in surface sediments. The crustal average of arsenic is found close to 2 mg $kg^{-1}$ (Tebbutt, 1983). Sedimentary rocks have higher arsenic contents than igneous and metamorphic rocks

(Boyle and Jonasson, 1973). Coal can contain arsenic as much as 2000 mg $kg^{-1}$ (Onishi, 1969).

Soil acts as the major sink of arsenic input to the environment, either through the natural processes or through the use of contaminated groundwater for irrigation. As most of the arsenical residues have low solubility and low volatility, they generally accumulate in the top soil layers. Soil serves as an important medium for accumulation, transformation and migration of such arsenic input. It is in this context that a thorough understanding of soil-arsenic interactions is important in order to judge as to how well such a sink be able to contain the toxin, and prevent it from entering the food chain through plant uptake and leaching to surface run-off and groundwater, and also to examine the possibility of it's biomagnification as it moves up the food chain.

High annual rainfall (1300 – 1600 mm), improved soil texture as well as fertility status and adequate irrigation potentiality (64 % of which is met through groundwater source) facilitates a high (300 % or more) cropping intensity in the arsenic affected areas of West Bengal. Besides, farmers of this region have the prevailing tendency to: (i) select high water requiring crop such as summer/*boro* paddy in the system of cropping and (ii) irrigate the crop field with water in excess of the actual requirement. Rice (summer/*boro*) - rice (wet/*kharif*) system is, by far, the most predominant system of cropping in the affected area. Groundwater in the affected belt occurs at a shallow depth of 5 to 15 m in dry season while the Central Groundwater Board observed 30 to 50 % lowering of groundwater during January to April, whereas the fluctuation of the depth to groundwater table during the same period is between 2 - 9 m (Sinha Ray, 1995). This is mainly attributed to the factors mentioned above which ultimately lead to an unlimited use of groundwater mainly from intermediate (20 – 80 m below ground level) aquifer which seems to be primarily responsible for arsenic mobilisation in groundwater and simultaneously acts as an input to soil arsenic contamination. The build up of arsenic in soil may prove detrimental to plants through it's uptake to the toxic limit, thereby entering the food chain. The possibility of bio-magnification in course of the travel of the toxin up in the food chain is also of natural concern.

Under such situation there is a need to develop an appropriate crop cafeteria with crops having low water demand and high market value towards proper utilization of various water resources.

The magnitude of peril confirmed the fortitude to plan the present investigation on different systems of cropping with crops having low water demand/requirement as well as high value and market demand with the following objectives in the arsenic affected areas of Chakdah block (Gotera Mouza) of Nadia district of West Bengal:

(i) to generate information on various cropping systems which would reduce the pressure on groundwater resource for irrigation especially during the lean period;

(ii) to find out some alternative and ideal crop sequences which have relatively low water demand throughout the year as well as have high demand and value in the market compared with the traditional winter (*aman*) rice – summer (*boro*) rice sequence;

(iii) to examine the uptake of arsenic (arsenic concentration) in the economic products as well as in various plant parts at different stages of growth besides uptake of N, P and K by the different component crops under various systems of cropping;

(iv) to analyse the growth attributes like LAI, CGR, DM accumulation at various stages of growth of the component crops and to find out whether there is any development of abnormality in growth behaviour of the plants;

(v) to study on the yield of crops in various cropping systems for economic evaluation and statistical analyses;

(vi) to study on the change (if any) in the available arsenic as well as N, P and K contents in soil after growing each crop, each sequence and at the end; and

(vii) to study the rooting behaviour of crops raised in the arsenic affected soil and subjected to irrigation with water containing arsenic.

# Chapter 2

# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

Agriculture is the way of life in India. The development in agriculture in India took a rapid stride with the introduction of HYVs of crops, chemical fertilizers, etc. leading to intensive cropping in order to feed the over burgeoning population. Indiscriminate use of chemical fertilizers, pesticides and other inputs of agriculture have brought about numerous soil and water related problems. In order to sustain the quality of environment and preserve the natural resources without affecting the food production, the need to focus on the choice of crops and cropping systems best suited in an environment both ecologically that maintains the quality of our natural resources and economic as well.

## 2.1 Formulation of cropping sequences

The problem of arsenic contamination in groundwater, in West Bengal, is said to be primarily due to heavy withdrawal of groundwater during the dry season consisting of summer months for summer rice cultivation. Rice is the main crop of the region during the wet season. Growing one or two crops before and after the main crop of *kharif* rice is possible. But the answer to the problem centres around substituting summer rice with suitable crops, which may fit well in the rotation having low water demand; besides being remunerative. Oilseed crops and legumes, having low water demand, were found to fit well in winter rice-based cropping sequences thereby could suitably be grown to replace summer rice. Sharma *et al.* (1982) found similar trend with jute-maize-wheat sequence.

## 2.2 Effect of a preceding crop on the succeeding crop in the system

Crops were found to exert some influence, either positive or negative, upon the crops grown after them. Sadanandan and Mahapatra (1972c) observed positive effect of jute in rice-jute-rice and groundnut-jute-rice sequences while continuous cropping without any legume was found to decrease the yield of maize by 50%.

Effect of legumes to increase total N, available phosphate and available potash contents of soil as compared to other summer crops were demonstrated by Nair *et al.* (1973a). Sadanandan and Mahapatra (1973 a) found more N in soil having groundnut or other leguminous crops in rotation.

Inclusion of legumes like greengram, gram, cowpea, etc. in sequence resulted in increased growth and grain yield of maize to the tune of 0.7-0.8 t $ha^{-1}$ (Ahlawat, 1981); while yield increased to the tune of 1.2-1.3 t $ha^{-1}$ of rice when raised after legume. Residual effect of summer crops such as *dhaincha* as green manure, greengram, groundnut, sesame, maize or cowpea on the yield of rice in the subsequent wet and dry seasons were found to be the same (Tajuddin *et al.,* 1989). The crop productivity and production economics increased in rice after jute in a system of cropping like wheat-jute-rice giving rise to the positive effect of jute crop on rice and inclusion of jute in rotation was found to decrease the net loss of N and increased the total N and organic C contents of soil as well as enriched the soil with available P (Mukherjee, 1991).

## 2.3 Maintenance of soil fertility under intensified cropping

Under intensive cropping, the soil is given little or no 'rest' to recover from either nutrient stress or nutrient depletion. After reviewing the crop rotations in India, Mirchandani and Sen (1956) stated that rotations of higher intensity improved the soil productivity more than those of lower intensity and the inclusion of legumes resulted in increase of N content of soil, as compared to rotation consisting of cereal crops only. Inclusion of berseem or grain legumes in rotation improved the N status of soil (Sharma and Saxena, 1968).

A preceding crop of jute was found to increase soil N considerably through it's contribution of leaf fall, rich in nitrogen, to the succeeding rice while in pulse-wheat rotation, total N content of soil was lowered after wheat (Yadav, 1985).

Long term fertilization on soil N balance under rice-wheat cropping system was studied by Verma and Yadav (1988) and showed that depletion in N status in soil occurred only in control plots (no nitrogen) or with lower doses of N. At higher levels, considerable build up of soil N was noticed and the degree of gain over initial status was more at 120 kg compared with 80 kg N $ha^{-1}$.

Van de Goor (1995) noticed one peculiarity that in spite of rice being grown year after year, even sometimes two crops in a year for centuries having little attention towards manuring, the yield appeared to have been maintained at a fairly uniform rate.

## 2.4 Rice-based cropping systems

The extensive adoption of the technological innovation of the late sixties in rice farming and rice –based cropping systems led the way to the growth and stability of food grain production in the country. Rice alone contributed 40.66% of the total food grain production , followed by wheat (34.7%). Out of the thirty important cropping systems so far identified in the country, rice-rice system of cropping occupied the second position in respect of acreage in the country covering an area of 6 m ha under various eco-systems and agro-ecological regions (Nair *et al.*, 1998).

Jain (1961) suggested that for raising the level of production of cereals in the country, a shift from low yielding crops to high yielding *rabi* crops in rotation with rice, might be an important step with the increased facility of irrigation. Winter paddy lands might be brought under double cropping with jute (Rao and Vachhani, 1964), with barley and gram (Shahi, 1973), with potato (Mishra *et al.,* 1976), with direct seeded rice and cowpea/maize (Malik *et al.,* 1980).

Kumar *et al.* (1993) conducted an experiment for investigating the performance of different summer crops raised in rice fallows, their influence on the succeeding rice crop and the economics of the whole system for a period of five years and revealed that among the summer crops, bhindi, vegetable cowpea and groundnut gave reasonably good receipts during the 3rd crop season.

Field experiments were conducted in Rajendranagar, Hyderabad, to evaluate production and profitability of different rice-based cropping systems in which rice-sunflower-greengram emerged as the most dependable one with regard to yield and *profit* $ha^{-1}$ $annum^{-1}$. *The available N and K status in the soil were maintained while the* status of P was enormously increased at the end of three years as compared to the initial soil test values (Mohammad, 1996).

Ghosh *et al.* (1996) conducted field study to find out the feasibility of maize, mungbean, groundnut and sesame in rice fallows (sown after harvest of rice). No significant difference in yield of maize was found on either of it's crop stands tested. However, higher yield was obtained at it's pure crop stand as well as it's intercrop stand with groundnut at 1 : 1 ratio.

In a field trial of twelve rice-based cropping sequences tested in the medium-lowland, alluvial tract, triple crop sequence of Jaya as autumn rice followed by rice (TTB 131-313-2) as winter rice and pea variety Rachna as dry season crop was found to be the most productive. It recorded a mean equivalent yield of 8.51 t $ha^{-1}$, mean production efficiency of 26.80 kg $ha^{-1}$ $day^{-1}$ and mean annual net return to the tune of Rs12,968 $ha^{-1}$. The double crop sequence consisting of Mahsuri as autumn rice followed by pea as dry season crop recorded the highest net return to the extent of Rs13,624 $ha^{-1}$ in spite of lower mean equivalent yield of 6.49 t $ha^{-1}$ (Thakuria *et al.*, 1996).

Kalia *et al.* (1999) conducted field trials for four years to find out the potential and alternate sequence in lieu of the traditional rice-wheat sequence under mid hill conditions of Himachal Pradesh and found rice-spring potato sequence to be the most productive and remunerative followed by rice-wheat and rice-gram sequences. Rice-spring potato recorded a mean rice equivalent yield of 24.9 t $ha^{-1}$ as against 15.0 t $ha^{-1}$ for rice-wheat system. The mean returns over variable costs was found to be the highest in rice-spring potato sequence followed by rice-wheat and rice-gram. The feasibility of growing an additional crop of short duration like toria in rice-spring potato sequence, as catch crop, by adjusting the sowing/transplanting of a suitable rice cultivar was shown.

## 2.5 Effect of preceding legume crop on succeeding crops grown in a sequence

It was estimated that out of 100 m t of nitrogen fixed annually, the largest part came from symbiotic sources especially through the nodules of leguminous plants.

The yield of ragi was found to increase by about 30% when grown in rotation with groundnut. A higher concentration of mineral N in the top soil after groundnut crop had been reported (Jones 1974). Legumes have played an important role in sustaining the productivity of the soil and benefitted the agricultural economy in India (Rachie and Roberts, 1975).

There were several reports that inclusion of legumes in the cropping systems had benefitted the associated crops, through improved soil nitrogen status and thereby reducing N application to the succeeding crop (Palaniappan *et al.,* 1976) and helped to save upto 5% of the recommended level of N application to the associated cereal crop (Morachan *et al.,* 1977).

Dhilon and Dev (1979) reported an increase in available N status of soil after the cropping of groundnut. Significant residual response to wheat after legumes had been reported by Biswas *et al.* (1979). Considerable economy in N use to wheat was realised when wheat was grown after groundnut compared with some other legumes.

Ahlawat *et al.* (1981) reported that inclusion of legumes in crop rotations increased the soil fertility and consequently the productivity of the succeeding cereal crops. Antil *et al.* (1989) reported that grain yield and N uptake were the highest when the preceding crop was *dhaincha* followed by moong, maize and fallow. Yadav (1990) reported that yield of succeeding wheat crop was higher after mungbean and urdbean as compared to fallow; the wheat yield obtained at 120 kg N $ha^{-1}$ could be obtained with the application of 90 kg N $ha^{-1}$ provided preceding crop of urdbean receiving 10-20 kg N $ha^{-1}$.

## 2.6 Jute-based crop sequences

Based on some long term experiments conducted at CRIJAF, Barrackpore, West Bengal (1994), it was reported that hardly 15% of the total jute growing area was covered under irrigation; out of which 70 to 80% areas were brought under the limited supply of water where farmers could provide only one irrigation either for germination or for sustenance of the crop.

Rao and Prasad (1978) conducted an experiment for four years at CRRI, Cuttack, in an upland ecosystem and concluded that three crops could easily be grown with jute as the main crop.

In a study, conducted during 1978 to 1981, regarding the suitability of jute in a multiple cropping programme in Assam, it was revealed that jute-wheat and jute-maize-wheat rotations gave rise to higher net profit than the rotation comprising jute alone (Sharma *et al.*, 1982).

## 2.7 Effect of green manure on the following crops in sequence

*Sesbania rostrata*, a new introduction in India, formed N fixing nodules on root as well as on stems and had 50 times more nodules than most legumes (Dreyfus and Dommergues, 1981). Dreyfus *et al.* (1985) reported that stem nodulating legumes like *S. rostrata* usually showed high sensitivity to climatic variations, particularly temperature and photoperiod.

Mandal *et al.* (1992) obtained higher yield and better growth in rice when green leaf manuring was done while incorporation of *Azolla* was found to improve soil physical and chemical properties. Incorporation of green leaf manure was found to influence growth and yield of succeeding rice to a greater extent (Mandal *et al.* 1992). Mandal *et al.* (1993a and 1993b) found similar response of *Azolla* and other organic manures in both summer and winter rices.

In a field experiment in Karnataka, grain yield produced with green manuring of *S. rostrata* alone was found to be equal to or more than the yield obtained with the application of recommended dose of N to rice crop; the highest grain yield was obtained with the combined application of green manure and 100% recommended dose of N (Matiwade and Sheelavantar, 1994).

Experiments carried out at Palampur (HP), to study the influence of green manures on nutrient content in rice, indicated that N, P and K contents in grain and straw were significantly affected by different green manures. *Dhaincha* resulted significantly in higher NPK contents as compared to the treatments which had frenchbean as green manure. Furthermore, all the treatments including *dhaincha* alongwith 50%, 75% and 100% NPK fertilizers to rice were found to be at par with each other. Similarly, frenchbean treatments remained on par with one another though the contents were quite lower (Bindra and Thakur, 1996).

A pot culture experiment was conducted by Sriramachandrasekharan *et al.* (1996) to study the effect of organic manures and biofertilizer, *viz*, *Sesbania aculeata*. *S. speciosa*, *Crotolaria juncea*, *Azolla microphylla*, cowpea, FYM, composted coir pith and paddy straw tested at N equivalents of 100 kg $ha^{-1}$ on the availability of nutrients with rice cv. IR 60 as the test crop. Higher availability of organic carbon, N, P, K, Zn, Fe and Mn were found through the incorporation of *S. aculeata*; however, *S. aculeata* and paddy straw were found comparable with regard to available K, Fe and Mn.

In a field experiment, it was observed that *C. juncea* and 60-day old *S. rostrata* produced comparable biomass and were significantly better than 45-day old *S. rostrata* and *S. aculeata*. The incorporation of different green manures significantly increased the soil $NH_4^+$-N upto 31 DAT. *S. rostrata* was found to release N at higher rate than *S. aculeata*. Increase in rice grain yield due to green manuring was not significant. All the green manures, except *S. aculeata*, produced significantly higher straw yield as compared to without green manuring (Chandra and Pareek, 1998).

## 2.8 Inclusion of oil seed crops in sequence

The productivity of different rice-oilseed crops, evaluated all over India, showed rice-mustard system as the most remunerative in arid, semiarid, sub-humid, humid and coastal ecosystems of India (Annual Report, Project Directorate for Cropping System Research, Modipuram (1998).

Chakroborty (1990) suggested that after harvest of upland paddy or jute in July, transplanted rice was possible to be grown during late July or early August and after the harvesting of *kharif* rice, *rabi* oil seeds or pulses could successfully be grown under rainfed conditions in Murshidabad district of West Bengal.

## 2.9 Maize as a component crop in cropping sequences

Govindakrishnan (1989) found the feasibility of developing maize/wheat-based cropping sequences in NW Plains of India and inclusion of potatoes either as an intercrop or parallel crop or in sequence provided higher net return while in a 2-year study, Reddy and Bheemaiah (1991) did not found any influence of cropping systems on grain yield, stover yield and harvest index of maize grown on two soil types.

In Madhya Pradesh, 3 potato-based cropping sequences were evaluated alongwith the most widely practised maize-wheat-cowpea. All potato-based cropping sequences had lower land utilisation index than maize-wheat-cowpea which had the highest potato-equivalent yield. Soybean – potato – okra was the most profitable one followed by maize – potato – greengram sequence (Nandekar *et al.*, 1992).

Regarding intercropping with maize, Jeyaraman *et al.* (1988) obtained highest net return in simultaneously sown maize + cowpea (with extra 25 kg N $ha^{-1}$) which also had the highest LER value.

Dhingra *et al.* (1991) studied the LAI and spatial distribution of solar radiation in different maize and mungbean intercropping systems and found an additional yield of 250 to 350 kg $ha^{-1}$ of mungbean in different sequences. Maize yield was highest in intercropping system.

### 2.10 Effect of cropping system on economy of crop production

Swaminathan (1972) stated that multiple cropping not only helped to increase the income of small farmers but also generated considerable additional employment. Rao and Prasad (1972) found a net income of Rs 4,425 to Rs 5,145 $ha^{-1}$ by growing jute-rice-wheat or blackgram or mustard on uplands. Green manuring with *dhaincha* and inclusion of jute crop in transplanted rice-wheat was found remunerative (Das and Karmakar, 1976).

A 2-year rotation of rice-wheat/sugarcane/potato/moong gave the highest rice equivalent grain yield (15.4 t $ha^{-1}$). The best one year rotation was rice- toria/wheat/*V. mungo* (12.3 t $ha^{-1}$). The highest benefit : cost ratio and net return were achieved with rice-linseed/fodder maize (Kharwara *et al.,* 1987).

### 2.11 Arsenic in soil – plant system

Introduction of high yielding varieties of crops during the late sixties and early seventies increased the demand for associated inputs mainly inorganic fertilizers and irrigation especially from the groundwater source. The widespread cultivation of *boro*/summer rice further enhanced the use of groundwater resource. On the contrary, land and water resources are limited and need their proper use. The widespread arsenic contamination in groundwater in parts of West Bengal has been reported to be primarily due to heavy withdrawal of groundwater especially during the lean months (Mandal *et al.*, 1996). In order to have an easy understanding of the source of the problem and the behaviour of arsenic in the soil-plant system under various cropping sequences, the literatures related are given below.

## 2.12 Sources of arsenic

A general understanding of the natural occurrence and the chemical and mineral forms of arsenic in the surface environment is of paramount importance in assessing the sources and pathways contributing to human exposure. Soil – an important natural resource for mankind serves an important medium for accumulation, transformation and migration of the toxicant–arsenic. Though small amounts of native arsenic could be found, but was mostly found combined with either iron or nickel or with sulphur. Arsenic, in soils, might originate from the soil and from industrial waste discharges or through the use of arsenical compounds in agriculture. The natural content of arsenic in soils was about 5 ppm (Backer and Chesnin, 1975) or sometimes 6 ppm while the level became much higher in arsenic contaminated soils.

### 2.12.1 Geological or sources of arsenic from parent material

The sources of arsenic in soil are mainly the parent materials from which it is derived. Arsenic is concentrated mainly in magmatic sulphides and iron ores. Some commonly found arsenic minerals are listed below:

| | | |
|---|---|---|
| **Sulfides** | Realgar | $AsS$ |
| | Orpiment | $As_2S_3$ |
| | Arsenopyrite | $FeAsS$ |
| **Sulfosalts** | Tennanite | $(Cu, Fe)_{12} As_4S_{13}$ |
| | Enargite | $Cu_3AsS_4$ |
| **Arsenates** | Scorodite | $FeAsO_4.2H_2O$ |
| | Minsetite | $Pb_5(AsO_4)_3Cl$ |
| **Arsenites** | Trippkeite | $CuAs_2O_4$ |

Uncontaminated soils usually contained 1-40 mg $kg^{-1}$ arsenic with lowest concentrations in sandy soils and those derived from granites while higher concentrations were in alluvial soils and in organic soils. Arsenic concentrations might go upto 8000 mg $kg^{-1}$ in soils in the proximity of sulphide ore deposits (Levander, 1977). Arsenic was usually present in higher concentration in soils than those in rocks (Peterson, 1981). When rocks weathered, arsenic might had been mobilised as salts of arsenous and arsenic acid (Irgolic *et al.,* 1995). Roasting of arsenic-containing ores and burning of arsenic-rich coal released arsenic trioxide, which might react in air with basic oxides to form arsenates and thereafter was deposited on to soils (Irgolic *et al.,* 1995).

### 2.12.2 Sewage-sludge and other industrial wastes

The huge amount of refuge from domestic and municipal wastes, particularly of highly concentrated population, the effluents having more or less toxic amounts of heavy metal discharges were found to play a major role to the problem of soil and water pollution. In Japan, paddy fields polluted with arsenic from the Sasagadmi mine were scattered throughout the prefectures of Miyagi, Shiamine, and Oita; the wastes produced from the mine affected the levels of arsenic, vast amounts of which were carried by rain or wind or by some rivers into paddy fields where the maximum concentration of arsenic in the soil was found (Suzuki *et al.,* 1974).

### 2.12.3 Agricultural chemicals and other sources

A survey of Wisconsin potato fields in 1970 to assess contamination with applied sodium arsenate showed that total arsenic in soils ranged from 2.25 to 25.7 ppm and was generally related to the amount applied (Steevens *et al.,* 1972). Many orchard soils in Missouri were treated with lead arsenate for 20-80 years, causing the concentration of arsenic in the soils to increase a level in excess of 100 ppm (Hess and Blanchar, 1977).

Mok and Wai (1994) reported that arsenic mobility was promoted by the incorporation of soluble phosphate as fertilizer and detergent. From the arsenic bearing minerals arsenate was replaced through leaching by such applied phosphate.

## 2.13 Groundwater contamination with arsenic

While explaining arsenic in groundwater of the Western United States, Welch *et al.* (1988) reported that arsenic mobilisation in sedimentary aquifers might had resulted partially from changes in geo-chemical environment due to withdrawal of groundwater to provide agricultural irrigation. In the deeper sub-surface, elevated arsenic concentrations were associated with compaction caused by groundwater withdrawal.

Bhumbla and Keefer (1994) gave a comprehensive cycle of arsenic transfer in the environment (Fig. 1a; the bold arrows indicate the main modes of transfer, namely, air, mining, pesticides, etc.).

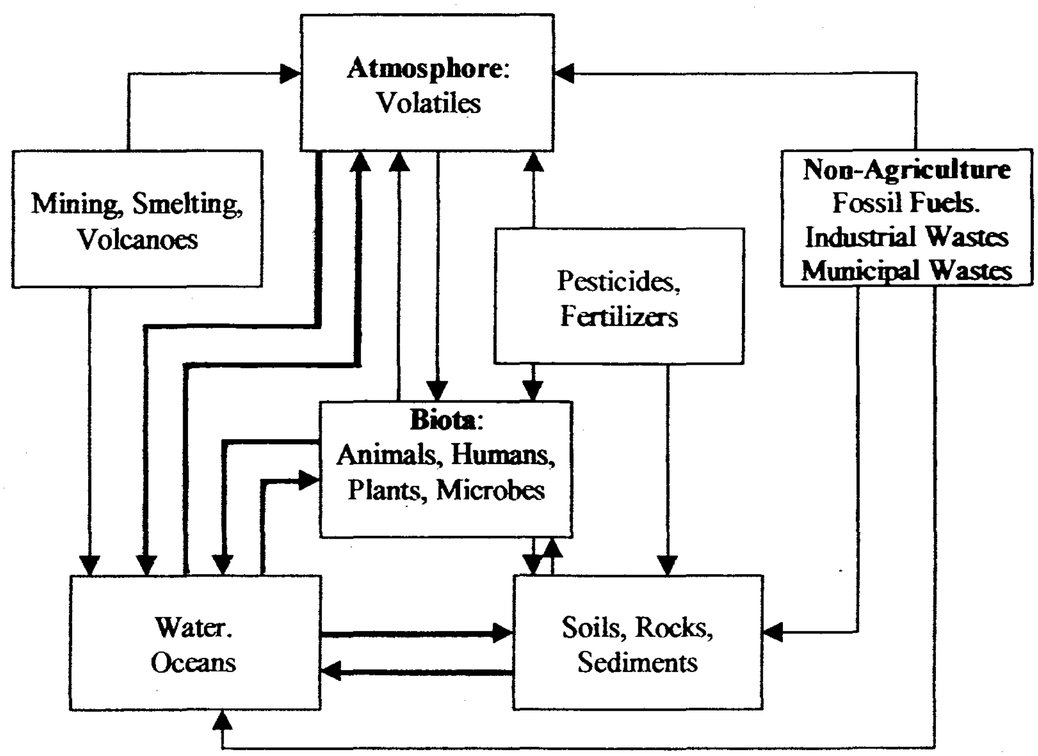



**Fig. 1a : A simplified, comprehensive cyclic transfer of arsenic in the environment**

The concentration of As in unpolluted fresh water typically ranged between 1 to 10 mg $l^{-1}$, rising to 100 to 5000 mg $l^{-1}$ in areas of sulphide mineralisation and mining (Fordyce *et al.,* 1995) while retention of 'As' in solution was linked by coprecipitation with elements such as Fe, Ba, Co, Ni, Pb, Zn, etc.

Complex organic arsenic compounds such as tetramethyl arsonium salts, arsenocholine, arsenobetaine and arsenic containing lipids had been identified in the marine environment (Irgolic *et al.,* 1995). Only a very minor fraction of total arsenic in the oceans remained in solution in sea water, as the majority was sorped on to the suspended particulate material.

Chakraborty and Saha (1995) suggested that large scale seasonal withdrawal of groundwater and influence of phosphatic fertilizers had major role in arsenic contamination of groundwater. Heavy withdrawal of groundwater causes fluctuation in the water table. Furthermore, change in the oxygenation state of groundwater at different depths might be responsible for arsenic contamination in groundwater.

The genesis of arsenic in groundwater in West Bengal was reported by Sinha Ray (1995). Leaching of arsenic in groundwater might be due to several interacting factors: application of phosphatic fertilizers, properties of iron oxides present in the soil, microbial reaction within the soil, groundwater withdrawal for irrigation and percolation of oxygenated water through soil might be responsible for the downward mobilisation of arsenic.

SinhaRay (1995) identified major clay horizons as the principal source of As. During the lean months, the depth of groundwater table generally varied from 2 m to 9 m in the arsenic – affected districts. Water from shallow aquifers (below 50m) showed a higher concentration of As while water from intermediate and deep aquifers (more than 150 m below) had been found to be free from As although water from a borewell as deep as 240 m in N 24-Parganas was found to contain high level of arsenic (GSI, 1996).

Sinha Ray (1995) indicated that the practice of cultivation of high water intensive summer paddy which required about 100 to 120 cm of irrigation water during the lean period aggravated the problem; the groundwater availability in the aquifer was at it's minimum at that period.

A recent study conducted by GSI (1996) led to the conclusion that most of the affected areas of West Bengal lay within the quaternary sediments of deltaic plains of the Bengal basin. The study emphasized that several geological factors might had provisionally led to arsenic mobilisation, the precise mechanism by which arsenic was mobilised into the water were yet to be understood.

Mandal *et al.* (1996) referred to a simple calculation of water withdrawal and the amount of arsenic in that water from a single Rural Water Supply Scheme supplying water to a few villages in Malda district, supplying 150,000 litres of water to the villages at a time having an arsenic concentration of 0.54 mg $l^{-1}$ in the water. Therefore, water withdrawal from the tubewell year$^{-1}$ (supplying water 5 times a day) was 273,750,000 litres and the total arsenic withdrawn year$^{-1}$ was 147.825 kg. This indicated that the possible source was geological. The study further indicated that arsenic-rich sediments were present in layers and existence of arsenic in pyrite was indicated.

## 2.14 Arsenic in soils

Huang Yan-Chu (1994) enlisted the range of arsenic content in soils: 0.80 to 22 mg kg$^{-1}$, 0.01 to 626 mg kg$^{-1}$ in the contaminated soils of Argentina and China, respectively, while it was 5 to 6 mg kg$^{-1}$ and 10 mg kg$^{-1}$ in Austria and Belgium, respectively.

## 2.15 Arsenic forms in soil

The solubility, mobility, bio-availability and hence toxicity of arsenic depended on its chemical forms, primarily the oxidation state. Arsenite [As(III)] and arsenate [As(V)] were the main arsenic species in soil. Arsenite, *i.e.,* the reduced from was much more toxic, more soluble and mobile than the oxidised form, As (V) (Levander, 1977).

## 2.16 Mechanism of arsenic mobilisation in groundwater in Bengal basin

There were two major hypotheses proposed as to the mechanism of arsenic mobilisation in Bengal basin : according to the first one, either iron bearing minerals brought along by rivers as part of the alluvial sediment, or formed *in situ* combined with sulphur under reducing condition, forming iron pyrites ($FeS_2$), which might had associated arsenic (Chakraborti *et al.,* 1992; Chatterjee *et al.,* 1995; Mandal *et al.*, 1996). A depthwise examination of 51 borehole sediment samples in 3 affected districts of West Bengal revealed the existence of arsenopyrite (Mandal *et al.,* 1996) which might act as source of arsenic. Withdrawal of groundwater, especially during the lean period (January to April), for cultivation of summer paddy had been stated to cause geochemical changes in the aquifer sediments through increased access of atmospheric oxygen, leading to oxidation and oxygenated decomposition of pyrite with the resultant formation of Fe (II) and Fe (III) sulphates and sulphuric acid, with the concomittant arsenic mobilisation into groundwater.

The hypothesis regarding possible mode by which arsenic found its way into groundwater in West Bengal and Bangladesh, stated that presently it might not be known whether the arsenic concentration in groundwater had been always high in the aquifer, or whether the concentration had increased as a consequence of groundwater development (Bhattacharya *et al.,* 1997). The authors suggested a rock in the Chhotonagpur – Rajmahal hills of Bihar in eastern India to act as the bedrock source of the said contamination. The arsenic present in iron pyrite or arsenopyrite had been deposited in the sediments, and partly redistributed there. The part contained in clays might had remained in the original form, while that in the sandy sediments might had undergone oxidation and been adsorbed onto ferric oxyhydroxide coatings on the sand grains.

SinhaRay (1997) considered that leaching of arsenic, occurring in aquifer sediments, was influenced by pH of water, properties of iron oxides present, application of phosphatic fertilizers and microbial reactions within the soil. He further opined that wetland paddy cultivation being practised in the affected areas of West Bengal might had aggravated the problem.

Nickson *et al.* (1998) proposed that in Bangladesh, arsenic was released when arsenic-rich iron oxyhydroxides were reduced in anoxic groundwater, a process that solubilised iron while raising the groundwater bicarbonate level which had been proposed to be the efficient scavengers of arsenic, and in the Ganges aquifer sediments, available Fe and As were found to correlate well.

Ravenscroft and Ahmed (1998) visualised mobilisation of arsenic in groundwater as a two-phase process, namely, fixation of arsenic in the aquifer sediments, followed by the second phase of arsenic release alongwith iron **after burial** when pore water conditions change from oxidising to reducing.

### 2.17 *Arsenic in relation to plant nutrition*

Machlis (1941) described arsenic toxicity in plants, as consisting of root plasmolysis and wilting, followed by root discolouration and necrosis of leaves. The soluble arsenic concentration in soils, causing injury for pea, beans was reported to be 9 mg $kg^{-1}$, barley was injured by a soluble arsenic level in soil of 2 mg $kg^{-1}$ while rice by 7 mg $kg^{-1}$, whereas injury was reported for alfalfa upto 6 mg $kg^{-1}$ of soluble arsenic level (Bishop and Chisholm, 1962). It was concluded that visual symptoms of arsenic phytotoxicity were only apparent at the highest level of application of soluble arsenic (60 ppm) when the youngest, *i.e.*, the most succulent tissues started to wilt slightly and other tissues exhibited veinal necrosis.

Anastasia and Kender (1973) found the greatest arsenic accumulation of blueberry tissues in the roots and which thereafter translocated into the aerial organs in a decreasing order towards the leaves.

In *Pseudotsuga mensiesii*, it accumulated upto 2000-5000 µg $g^{-1}$ in plant ash (Hewitt and Smith, 1975) while high concentrations upto 16 µg $g^{-1}$ (dry weight) was reported in dandelion growing around smelters in Bulgaria (Djingova and Kuleff, 1993). No simple relationship was found between the total arsenic in soil and the rice yield in polluted fields in Japan (Kiyosue and Yano, 1975).

The relationship between the amount of arsenic in soil, plant growth and the corresponding arsenic toxicity depended on the form and availability of arsenic (Walsh *et al.*, 1977).

Kitagishi and Yamane (1981) found a mean As concentration of 0.19 µg $g^{-1}$ (dry weight) in rice grown on polluted soil while the root content was in the range of 936-1182 µg $g^{-1}$. Yields of rice, barley and alfalfa in cotton fields previously treated with As were found to decrease (Peterson *et al.*, 1981). Arsenic, a constituent of most plants, appeared to be phytotoxic and the toxicity of arsenite was reported to be greater than that of arsenate.

Takamatsu *et al.* (1983) reported that depression of rice growth seemed to depend on the amount of arsenite in soil and arsines (the gaseous form) damage the roots of rice, resulting in the inhibition of nutrient uptake. The toxicity of arsenic in various soils decreased in order: sandy soil > alluvial soil > black soil > red clay.

Arsenate could enter into reaction in place of 'P', thereby became a toxicant; there was strong evidence that arsenate was normally absorbed in a manner similar to the mechanism of uptake of phosphorus (Bileski and Ferguson, 1983). Arsenic levels ranging from 45 to 60 ppm caused significant reduction in plant weight.

Xu and Thornton (1985) surveyed 32 gardens in the Hayla-Camborne area in Cornwall having soil As concentration in the range of 144-892 $\mu g\ g^{-1}$. Arsenic in lettuce, onion, beet root, carrot, pea and beans were determined and showed increased arsenic contents (in all the vegetables) with increased 'As' content of the soil. The relationships between As contents of beet root, lettuce, onion and pea and both total and extractable As in soil were significant showing As levels in the edible tissues to increase with increasing soil As content.

Arsenic uptake was said to be passive and as it was not readily translocated to different parts of the plant, mostly being found in roots and old leaves (Streit and Stumm, 1993).

Arsenic accumulated in plants grown on soils contaminated by arsenic, thereby entering into the food chain; however, because arsenic was not readily translocated to shoots, most of the amount was found in the roots (Bhumbla and Keefer, 1994).

### 2.18 Relationship between soil arsenic and amount of arsenic in plants

Fujimoto *et al.* (1972) reported that residues of arsenic in grains and straws of rice were related to the content and form of arsenic in paddy soils. It was found that arsenate, when reduced, in submerged condition became highly soluble in soil and more toxic which was easily absorbed by rice plants and the contents of arsenic in stems, leaves as well as in roots of rice plants were found to be related to the changed content of arsenic in soil (Tensho, 1973). A positive correlation was found between extractable arsenic content in soil and the content of arsenic in the rice plant and it was higher in leaves, stems and in roots compared with its content in the panicles of rice plant (Koyama and Shibuya, 1976).

The content of arsenic in wheat plants increased with increasing soil arsenic levels (Jiang and Hao, 1983); the concentrations of arsenic in flour were 0.114, 0.203, 0.214, 0.235 and 0.293 ppm when the soil arsenic levels were 0, $< 20$, 20-30, 40-50 and $> 50$ ppm, respectively.

## 2.19 Critical concentration of arsenic in soil

Arsenic pollution in soil might had toxic effect in vegetation so much that 1 ppm soluble arsenic was found to cause injury to cowpea (Albert and Arndt, 1931), 7 ppm caused injury to rice (Epps and Sturgis, 1939), 2 ppm to barley (Vandecaveye, 1943), 9 ppm to beans and peas (Bishop and Chisholm, 1962). Deuel and Swoboda (1972a) reported that cotton and soybean yields were reduced when As concentration in tissues reached 44 and 10 ppm, respectively.

The arsenic concentration at which rice yield decreased by 10% was judged as the maximum allowable limit, or critical content of arsenic in soil. In Japan, 15 ppm was set as the maximum allowable limit of arsenic in soil (Yamane, 1979). Rice yield was reported to decrease by 10% at 25 ppm (Xiong *et al.,* 1987). In a pot experiment with rice soil, stanogleyed rice soil and red sandy rice soil, Xie *et al.* (1991) found the critical contents leading to toxicity of As in rice plants as mentioned in Table 2.1.

**TABLE 2.1**

**Critical arsenic content in soil leading to toxicity in rice plants**

| Soil | 50% growth reduction (ppm) | | No tillering (ppm) | | Death (ppm) | |
|---|---|---|---|---|---|---|
| | As (III) | As (V) | As (III) | As (V) | As (III) | As (V) |
| Rice soil | 130 | 160 | 170 | 210 | 210 | 310 |
| Stanogleyed rice soil | 75 | 85 | 110 | 115 | 169 | 269 |
| Red sandy rice soil | 47 | 52 | 69 | 77 | 109 | 157 |

## 2.20 Arsenic in plants grown on arsenic contaminated soil (arsenic tolerance by plants)

In a study, conducted to examine the arsenic toxicity to cotton and soybean grown on soils of light and heavy textured, Duel and Swoboda (1972b) noted that the toxic effect of arsenic was resulted from higher uptake by the plants regardless of the type of soil. For cotton, an increased As concentration of the plant (more than 4.4 mg $kg^{-1}$), vegetative growth declined by about 50%. An internal As concentration of 1.0 mg $kg^{-1}$ induced a significant decline in vegetative growth of soybean although fruiting still continued; however, no fruit was set in soybean at internal arsenic concentrations exceeding 6.2 mg $kg^{-1}$. The corresponding water soluble arsenic concentrations in the soils were, however, 3-4 times higher in the heavy textured soil as compared to the light textured soil, and were about 2-3 times lower for the soybean crop, relatively less tolerant between the two.

Some plants were found to be tolerant towards high concentration of arsenate but not arsenite. Some *Andropogon* plant species were reported to tolerate upto 1500 μg of As $g^{-1}$, with solution values of 25 μg As $ml^{-1}$ (Rochovich and West, 1975). *Agrostis tenuis* and *A. stolonifera* grew on smelter wastes accumulated arsenic upto 1% dry weight (Benson *et al.*, 1981) while *Cynodon dactylon* was found to grow well on a mine waste with 1890 mg of As $kg^{-1}$ (Hill, 1983).

Adriano (1986) had compiled the comparative tolerance of various crops to arsenic into: (i) low tolerant group (peaches, apricot, peas, onion, cucumber, snapbean, limabean, soybean, rice, spinach, alfalfa, clover, vetch, etc.), (ii) moderately tolerant group (cherries, straw berries, beet, corn, squash, turnip, radish, etc.) and (iii) highly tolerant group (apple, grape, raspberries, rye, asparagus, cabbage, carrot, tomato, potato, wheat, oats, cotton, tobacco, etc.)

Among the non-tolerant plants, arsenic was reported to be extremely toxic which could be alleviated through the addition of high concentrations of phosphate (Macnair and Cumbers, 1987).

Chan *et al.* (1992) reported that the range of arsenic content in the soils of Hunan Province was between 76 and 5092 mg $kg^{-1}$ with an average of 810.4 mg $kg^{-1}$.

A significant relationship between the arsenic content in rice grain and in root tubers of sweet potato as well as the total arsenic content in soils was obtained. The arsenic contents in soils, when As contents in edible parts of rice and sweet potato reached a critical value of 6-7 mg $kg^{-1}$, were 202 and 305 mg $kg^{-1}$ As, respectively.

Kiss *et al.* (1992) conducted pot trials using sandy chernozen soil (pH 6.0) and the effects of N, P, K and 50 mg and 500 mg $kg^{-1}$ As with spring barley cultivar 'Spartan' and with onion cv. 'Makoi' in which As was applied either through irrigation water or in soil and found that plant growth was reduced and leaves showed red/yellow discolouration. Supplemental Mg reduced 'As' uptake by 40-50% and reduced As content by about 30% in bulbs/grains. Uptake of As was greater via leaves than via roots in onions and irrigation with water containing As increased plant As content more than the soil As treatment.

### 2.21 Summary and scope of work

Cultivation of high water-intensive summer paddy has been thought to be responsible for arsenic mobilisation in groundwater in Bengal basin. Heavy withdrawal of groundwater to irrigate summer paddy has been reported to cause geochemical changes in aquifer sediment with concomittant arsenic mobilisation in groundwater.

Though arsenic contamination in groundwater in Bengal basin and the resultant health hazards has been detected long back, nevertheless, most of the researches on arsenic was, by far, conducted mainly on the aspects of water quality. However, reports indicated that arsenic accumulated in plants grown on arsenic contaminated soils and may reach toxic level and thereby enters into the food-chain. The possibility of bio-magnification in course of travel of the toxin up in the food chain is also of natural concern and it calls for immediate attention of the researchers.

Rice is one of the most important crops grown during the summer months covering large area. Research showed that some other crops having low water need besides remunerative could easily be fitted in cropping sequences in place of summer rice. Oilseed crops, *viz*, mustard, sesame have been found to fit well in a rotation and gave high economic returns. Pulses like greengram being short duration in nature could easily be fitted in any cropping sequence. Jute-based, maize (summer)-based cropping sequences have also been found to be remunerative and could easily be used as substitute of rice-rice sequence.

Summer rice has earlier been reported as low tolerant to arsenic accumulating arsenic in toxic levels. Besides, crops like wheat, mustard, maize, etc. also reported to accumulate arsenic to toxic levels causing reduction in plant growth and yield. Continued cultivation with arsenic contaminated irrigation water has been reported to increase the soil available arsenic level that may reach to levels becoming toxic and unfit for growth of the crops.

Till now, most of the research works has been conducted on crops, mainly vegetables, grown under controlled condition receiving graded doses of arsenic to study arsenic uptake by various plant parts, or otherwise build-up of arsenic has been studied on crops grown in arsenic contaminated soils around the world. The build-up of arsenic in various plant parts of crops in a rotation grown on arsenic contaminated soils receiving arsenic contaminated irrigation water and simultaneous arsenic uptake patter by various plant parts of crops in a rotation need to be thoroughly investigated.

# Chapter 3

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

To study the pattern of arsenic uptake and it's influence on growth and yield of different crops under various systems of cropping, a crop cafeteria was raised at the farmers' fields in the arsenic affected areas of Gotera Mouza under Chakdah Block, in Nadia District of West Bengal. Altogether, nine different cropping sequences were tried in medium land ecosystem; while rice-rice system, which was the most predominant cropping system practised by the farmers of the region was tried alongwith a green manure, in a typical low land ecosystem. The experimental field contained arsenic at varying levels while irrigation was supplied to all the crops in various cropping sequences from DTW 216 having arsenic content to the extent of 0.22 – 0.23 ppm (mg $l^{-1}$).

## 3.1 Location of the experiment

All the sequences under the investigation was conducted in the farmers' environment. The region was one of the most worstly affected and widely reported arsenic prone zone of West Bengal. The fields were located approximately at $23^0$ $3^{/}47^{//}$ North latitude and $88^0$ $36^{/}$ $42^{//}$ East longitude. The elevation was approximately 6 m above mean sea level. Physiographically the area was within the lower alluvial plain.

## 3.2 Pre-dominant cropping systems of the experimental area

More than 80% of the gross cropped area was reported to be under rice grown during both wet and dry seasons. Mustard and jute were the other two important crops, grown primarily in the region. In medium land ecosystem, rice-rice, jute-rice-mustard, pointed gourd-vegetable, sesame-rice-mustard, rice-mustard, rice-vegetable, rice-fallow-mustard, jute-rice, jute-fallow-mustard, taro (throughout the year) were the cropping sequences mostly followed in the region. About 44% during *kharif* and around 37% of the gross cropped area in summer were cropped under rice.

## 3.3 Land utilization pattern at Gotera

- Total geographical area 235.42 ha
- Total agricultural land 202.03 ha
  - a) Upland 32.05 ha
  - b) Medium land 143.89 ha
  - c) Low land 26.09 ha
- Cultivable fallow 4.03 ha

## 3.4 Climatic condition

The climate of the experimental area is broadly classified as subtropical humid. Broadly the seasons of the region are classified as: Pre-*kharif* and *kharif* or rainy season otherwise as pre-monsoon (from April – May), monsoon (from June – September), post-monsoon (from October – November) and dry (from December – March). Winter is short and mild whereas the temperature is usually high during the summer months. Relative humidity remains high during June – October. Most of the rainfall is received during the months of June to September. Groundwater level reaches the maximum depth (3.6 to 6.0 mbgl) during the pre-monsoon months (April – May). The details of the meteorological parameters pertaining to the period of experimentation are given in Table 3.1 and Fig. 1b, 2 and 3.

## TABLE 3.1

**Monthly. meteorological observation during the course of investigation (March 1998 to June 2001)**

| Month | Temperature (°C) | | | | Total rainfall (mm) | | Relative humidity (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum | | Minimum | | | | Maximum | | Minimum | |
| | LTA | Year | LTA | Year | LTA | Year | LTA | Year | LTA | Year |
| **1998** | | | | | | | | | | |
| March | 32.9 | 30.4 | 19.9 | 17.8 | 23.4 | 199.6 | 86.7 | 95.0 | 41.1 | 49.0 |
| April | 36.8 | 34.0 | 23.9 | 23.2 | 62.4 | 76.9 | 88.3 | 94.4 | 43.2 | 62.0 |
| May | 36.4 | 35.4 | 25.1 | 25.1 | 102.6 | 60.9 | 89.7 | 89.9 | 58.0 | 62.4 |
| June | 36.6 | 36.3 | 25.0 | 27.1 | 274.3 | 119.0 | 89.5 | 89.9 | 76.1 | 58.2 |
| July | 32.3 | 37.7 | 26.7 | 26.2 | 285.6 | 190.8 | 90.4 | 96.1 | 81.1 | 76.0 |
| August | 32.6 | 33.2 | 24.7 | 26.5 | 291.1 | 217.3 | 93.2 | 96.3 | 63.7 | 79.4 |
| September | 32.7 | 32.7 | 25.5 | 25.5 | 267.2 | 274.0 | 92.9 | 97.6 | 76.6 | 80.1 |
| October | 30.2 | 33.4 | 23.8 | 24.4 | 114.7 | 133.1 | 90.0 | 97.1 | 60.7 | 78.0 |
| November | 29.4 | 30.0 | 16.1 | 19.9 | 17.2 | 156.4 | 90.8 | 98.2 | 49.1 | 67.6 |
| December | 25.9 | 27.3 | 11.1 | 12.2 | 3.2 | 60.0 | 93.9 | 99.8 | 52.1 | 53.6 |
| **1999** | | | | | | | | | | |
| January | 25.4 | 25.9 | 9.9 | 9.9 | 7.6 | 0.0 | 93.7 | 99.4 | 59.2 | 57.5 |
| February | 27.8 | 30.0 | 13.2 | 14.5 | 7.9 | 0.0 | 94.0 | 98.4 | 51.2 | 43.7 |
| March | 32.9 | 34.7 | 19.9 | 20.0 | 23.4 | 0.0 | 86.7 | 93.9 | 41.1 | 36.9 |
| April | 36.8 | 37.3 | 23.9 | 25.5 | 62.4 | 1.4 | 88.3 | 93.1 | 43.2 | 51.5 |
| May | 36.4 | 34.9 | 25.1 | 25.3 | 102.6 | 158.0 | 89.7 | 91.8 | 58.0 | 62.3 |
| June | 36.6 | 34.2 | 25.0 | 25.8 | 274.3 | 277.5 | 89.5 | 93.5 | 76.1 | 74.5 |
| July | 32.3 | 32.5 | 26.7 | 26.0 | 285.6 | 635.1 | 90.4 | 97.1 | 81.1 | 82.2 |
| August | 32.6 | 32.3 | 24.7 | 26.0 | 291.1 | 251.3 | 93.2 | 97.1 | 63.7 | 82.2 |
| September | 32.7 | 31.5 | 25.5 | 25.3 | 267.2 | 411.4 | 92.9 | 97.6 | 76.6 | 84.8 |
| October | 30.2 | 32.0 | 23.8 | 24.4 | 114.7 | 414.9 | 90.0 | 98.3 | 60.7 | 73.1 |
| November | 29.4 | 30.2 | 16.1 | 17.4 | 17.2 | 8.0 | 90.8 | 98.0 | 49.1 | 55.2 |
| December | 25.9 | 27.6 | 11.1 | 13.0 | 3.2 | 0.0 | 93.9 | 99.0 | 52.1 | 51.3 |
| **2000** | | | | | | | | | | |
| January | 25.4 | 25.9 | 9.9 | 11.1 | 7.6 | 4.2 | 93.7 | 99.9 | 59.2 | 52.3 |
| February | 27.8 | 25.9 | 13.2 | 14.5 | 7.9 | 24.0 | 94.0 | 95.0 | 51.2 | 52.1 |
| March | 32.9 | 32.6 | 19.9 | 19.0 | 23.4 | 0.0 | 86.7 | 94.0 | 41.1 | 43.1 |
| April | 36.8 | 34.9 | 23.9 | 24.1 | 62.4 | 88.7 | 88.3 | 94.0 | 43.2 | 57.0 |
| May | 36.4 | 34.5 | 25.1 | 24.3 | 102.6 | 280.2 | 99.7 | 96.0 | 58.0 | 66.7 |
| June | 36.6 | 33.3 | 25.0 | 25.4 | 274.3 | 224.1 | 89.5 | 64.6 | 76.1 | 75.8 |
| July | 32.3 | 32.3 | 26.7 | 25.9 | 285.6 | 388.1 | 90.4 | 94.0 | 81.1 | 78.5 |
| August | 32.6 | 34.3 | 24.7 | 27.0 | 291.1 | 351.8 | 93.2 | 94.6 | 63.7 | 76.3 |
| September | 32.7 | 31.7 | 25.5 | 24.9 | 267.2 | 279.1 | 92.9 | 97.9 | 76.6 | 81.9 |
| October | 30.2 | 33.2 | 23.8 | 23.8 | 114.7 | 90.8 | 90.0 | 97.4 | 60.7 | 68.2 |
| November | 29.4 | 30.5 | 16.1 | 18.6 | 17.2 | 1.20 | 90.8 | 98.3 | 49.1 | 50.3 |
| December | 25.9 | 26.8 | 11.1 | 11.7 | 3.2 | 0.0 | 93.9 | 99.4 | 52.1 | 45.6 |
| **2001** | | | | | | | | | | |
| January | 25.4 | 25.3 | 9.9 | 9.5 | 7.6 | 0.0 | 93.7 | 99.4 | 59.2 | 41.8 |
| February | 27.8 | 29.8 | 13.2 | 14.6 | 7.9 | 24.5 | 94.0 | 95.8 | 51.2 | 38.1 |
| March | 32.9 | 33.5 | 19.9 | 19.1 | 23.4 | 123.0 | 86.7 | 94.9 | 41.1 | 38.3 |
| April | 36.8 | 35.8 | 23.9 | 23.6 | 62.4 | 90.1 | 88.3 | 94.1 | 43.2 | 44.5 |
| May | 36.4 | 35.0 | 25.1 | 22.9 | 102.6 | 284.3 | 99.7 | 92.4 | 58.0 | 64.8 |
| June | 36.6 | 32.6 | 25.0 | 25.5 | 274.3 | 226.7 | 89.5 | 96.6 | 76.1 | 78.7 |

LTA = Long term average

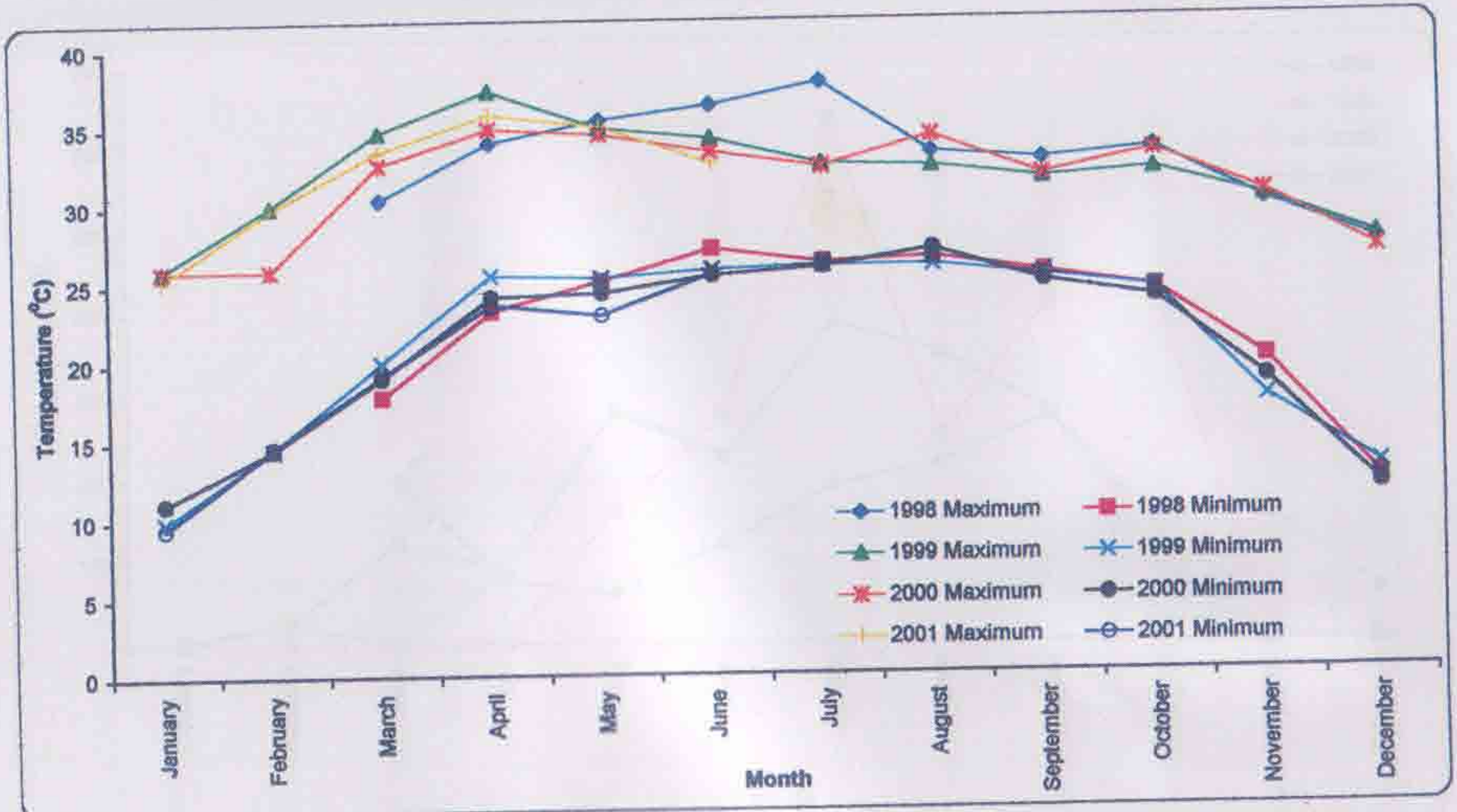



Fig. 1 b: Mean monthly temperature (degree celcius) pertaining to the period of experimentation

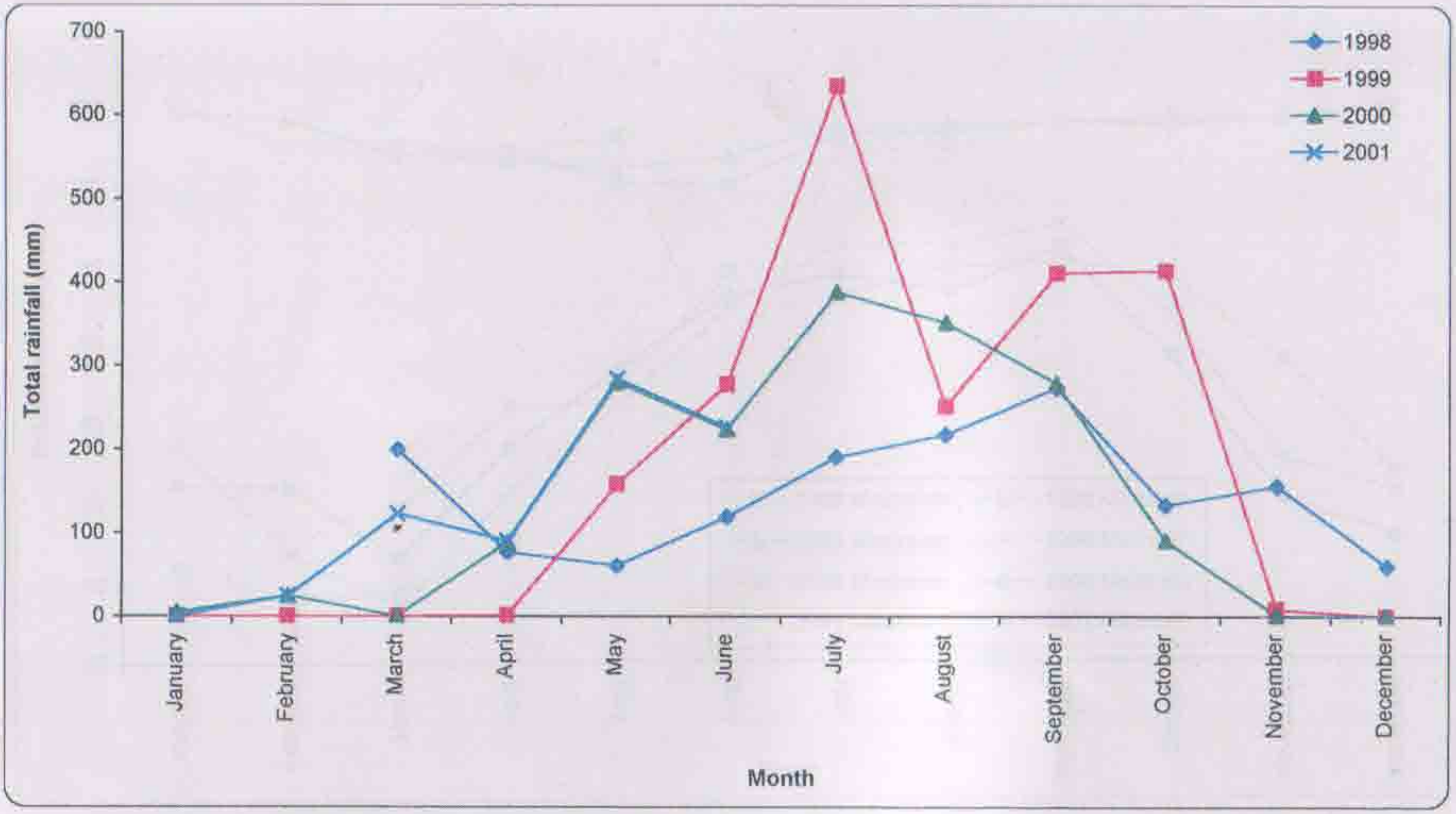



Fig. 2 : Monthly rainfall (mm) pertaining to the period of experimentation

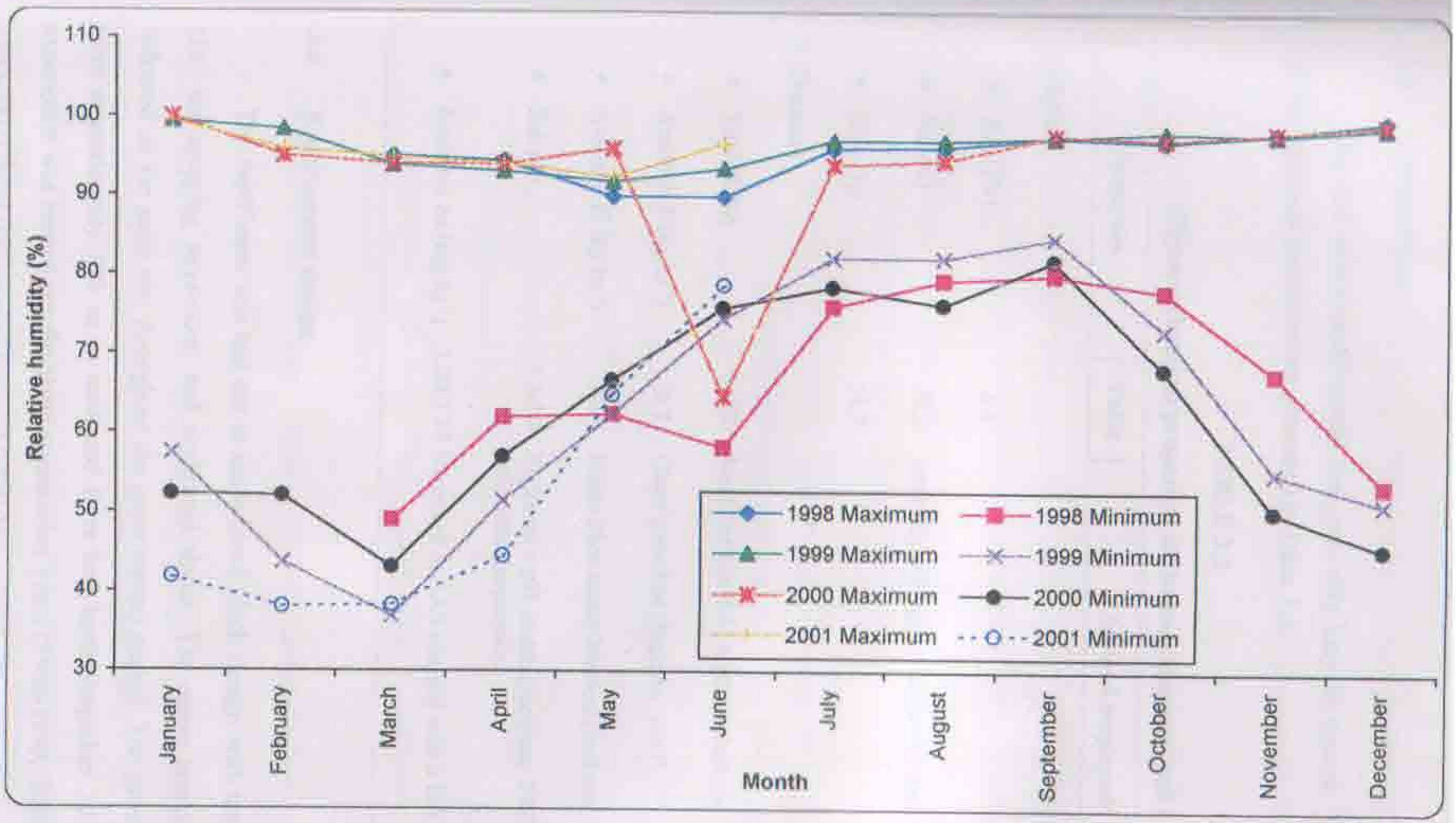



Fig. 3 : Mean monthly relative humidity (per cent) pertaining to the period of experimentation

## 3.5 Soil condition

The soil of the experimental area was silty clay in texture. The important physico-chemical properties are presented in Table 3.2.

**TABLE 3.2**

**Physico-chemical properties of the experimental soil**

| Properties | Value | Method employed |
|---|---|---|
| 1. Physical | | |
| ♦ Sand (%) | 6.1 | |
| ♦ Silt (%) | 72.2 | International Pipette Method (Piper, 1950) |
| ♦ Clay (%) | 21.7 | |
| 2. Chemical | | |
| ♦ Total N (%) | 0.071 | Modified Kjeldahl Method (Jackson, 1967) |
| ♦ Available P (kg $ha^{-1}$) | 29.7 | Olsen's method (Jackson, 1967) |
| ♦ Available K (kg $ha^{-1}$) | 218 | Flame Photometer Method (Jackson, 1967) |
| ♦ Soil pH | 7.3-7.4 | Backman's pH meter (Jackson, 1967) in 1 : 2.5 Soil-water suspension |
| ♦ Available As (mg $kg^{-1}$) | 1.20-1.37 | Measured in AAS coupled with a HG unit. |

## 3.6 Experimental design

The experiment was laid out in randomized block design with ten treatments (*i.e.*, ten cropping sequences) and replicated thrice. The same layout plan was followed on the same site throughout the experimental period. The gross plot sizes were approximately 100 sq m each and there had been altogether 30 plots. The experiment was carried out for three consecutive years (1998-1999, 1999-2000 and 2000-2001) under the command area of DTW 216.

### 3.6.1 Treatment details

The ten different cropping sequences, representing the ten treatments (including green manure - rice-rice system which acted as the control treatment), are given below:

1. **Maize** (March – June) – **greengram** (July – September) – **potato** (end of October – early February).
2. **Elephant–foot yam** (early April – September) – **maize** (mid October – end of January) – **greengram** (early February – early April).
3. **Elephant-foot yam** (May – mid October) – **mustard** (end of October – January) – **sesame** (early February – early April).
4. **Olitorius jute** (mid May - mid August) – **greengram** (end August –mid October) – **potato** (early November – early February) – **sesame** (2nd week of February – early May).
5. **Olitorius jute** (early May – early August) – **rice** (mid August – early December) – **rice** (January – April).
6. **Elephant-foot yam** (June – late October) – **wheat** (November – February) – **groundnut** (mid February – early June).
7. **Greengram** (March – May) – **rice** (July – October) – **mustard** (November – February).
8. **Green manure** (May – June) – **rice** (July – October/November) – **rice** (January – April).
9. **Maize** intercropped with **greengram** (March – June) – **greengram** (July – September) – **potato** (end of October – early February).
10. **Elephant-foot yam** intercropped with **cowpea** (early February – September) – **maize** (mid October – end January) – **greengram** (early February – early April).

### 3.6.2 Cultivars used

| | | | |
|---|---|---|---|
| Rice | : IET 4786 (Satabdi) | Maize | : Ganga Safed |
| Greengram | : B 105 (Panna) | Jute | : JRO 524 (Nabin) |
| Sesame | : B 67 (Tilottama) | Groundnut | : JL 24 (Phule Pragati) |
| Wheat | : UP 262 | Green manure (dhaincha) | : Local |
| Mustard | : RW 351 (Bhagirathi) | Potato | : Kufri Jyoti |
| Cowpea | : EC 4216 | Elephant-foot yam | : Kovvur |

These cultivars were most widely used by the farmers of the experimental area.

### 3.6.3 Spacing, seed rate and fertilizer dose of the crops

| Crop | Spacing (cm) | Seed rate (kg ha$^{-1}$) | Fertilizer dose N : P : K (kg ha$^{-1}$) |
|---|---|---|---|
| Maize | 60 × 20 | 18 | 120:26.20:50 (½ N, full dose of P and K as basal and rest ½ N was top-dressed at knee high stage before earthing up operation) |
| Greengram | 30 × 10 | 20 | 20:17.46:0 (as basal) |
| Elephant-foot yam | 70 × 60 | 6000 | 120:26.20:41.67 (½ N, P, ½ K as basal in the pit, rest ½ N and ½ K were top-dressed at 60 days after emergence of shoots) |
| Jute | 20 (row to row) | 7.5 | 60:13.10:25 (P and K as basal, ½ N was top-dressed at 3 weeks after sowing and rest ½ N at 6 weeks after sowing) |
| Rice (*aman*/winter) | 20 × 15 | 45 | 60:13.10:25 (¼ N, full dose of P and ¾ K as basal, ½ N top-dressed at active tillering stage and rest ¼ N and ¼ K at P.I. stage) |
| Rice (*boro*/summer) | 20 × 10 | 50 | 100:21.80:41.67 (time of application same as in *aman* rice) |
| Mustard | 30 × 7-10 | 6.0 | 80:17.46:33.34 (½ N, full dose of P and K as basal, rest ½ N was top-dressed at 3 weeks after sowing before giving first irrigation) |
| Sesame | 30 × 10 | 7.0 | 60:13.10:25 (½ N, full dose of P and K as basal and rest ½ N was top-dressed at branching stage before giving first irrigation) |
| Groundnut | 30 × 15 | 100 | 20:17.46:25 (as basal) |
| Potato | 40 × 15 | 2000 | 150:43.67:83.34 (½ N, full dose of P and K as basal, rest ½ N was top-dressed during 1st earthing up) |
| Wheat | 20 (row to row) | 100 | 100:21.80:41.67 [½ N, full dose of P and K as basal, rest ½ N was top-dressed before giving 1st irrigation at CRI stage (21 DAS)] |

### 3.6.4 Scheduling of irrigation to the crops

- **Maize (summer):** 4 irrigations – one each at knee high stage, tasselling, silking and grain-development stage, while the *kharif* crop was raised purely as rainfed.

- **Greengram:** 2 irrigations were given – one each at branching and pod development stage.

- **Elephant-foot yam:** First irrigation was given during emergence of shoots and subsequent irrigations were applied in case soil became dry before the onset of monsoon.

- **Jute:** 2 life saving irrigations were given.

- **Rice:** *Aman*/wet season : Rainfed

  *Boro*/dry season : Irrigated (continuous submergence of 2-5 cm depth).

- **Mustard:** 3 irrigations were given at branching, flowering and siliqua formation.

- **Sesame:** 2 irrigations were given one each at branching and capsule formation stage.

- **Groundnut:** 3 irrigations were given at branching, pegging and pod development stage.

- **Potato:** Ridge and furrow method of irrigation was adopted at an interval of 10-12 days depending upon the soil moisture condition.

- **Wheat:** 4 irrigations were given at CRI, maximum tillering, flowering and at milk stage.

### 3.6.5 Volume of water given to different crops through irrigation

| Crop | Number of irrigations given $ha^{-1}$ Cropping sequence* | | | | Depth of water given $irrigation^{-1}$ (cm) | Volume of water given through irrigation ($ha^{-1}$) app. Cropping sequence* | | | |
|---|---|---|---|---|---|---|---|---|---|
| Elephant-foot yam | (2) | (3) | (6) | (10) | 6 | (2) | (3) | (6) | (10) |
| | 7 | 6 | 5 | 7 | | 0.42 | 0.36 | 0.30 | 0.42 |
| Maize | (1) | (2) | (9) | (10) | 5 | (1) | (2) | (9) | (10) |
| | 3 | 4 | 3 | 4 | | 0.15 | 0.16 | 0.15 | 0.16 |
| Mustard | (3) | (7) | | | 4 | (3) | (7) | | |
| | 3 | 3 | | | | 0.12 | 0.12 | | |
| Greengram | (1) | (4) | (7) | (9) | - | (1) | (4) | (7) | (9) |
| | - | - | - | - | | - | - | - | - |
| Jute | (4) | (5) | | | - | (4) | (5) | | |
| | 3 | 2 | | | | 0.12 | 0.08 | | |
| Rice (a) Winter | | Rainfed | | | | | | | |
| (b) Summer | (5) | (8) | | | 6 | (5) | (8) | | |
| | 20 | 20 | | | | 1.2 | 1.2 | | |
| Groundnut | (6) | | | | 5 | (6) | | | |
| | 3 | | | | | 0.15 | | | |
| Potato | (1) | (4) | | | 6 | (1) | (4) | | |
| | 8 | 8 | | | | 0.48 | 0.48 | | |
| Sesame | (3) | (4) | | | 5 | (3) | (4) | | |
| | 2 | 2 | | | | 0.10 | 0.10 | | |
| Wheat | (6) | | | | 4 | (6) | | | |
| | 4 | | | | | 0.16 | | | |

* Numbers within parentheses indicate the cropping sequence numbers under the given crop cafeteria detailed earlier.

**TABLE 3.3**

**Volume of water applied to crop sequences through irrigation**

| Crop sequence | Total volume of water applied(ha-m) | |
|---|---|---|
| 1. Maize-greengram-potato | (0.15 + 0 + 0.48) | : 0.63 |
| 2. Elephant-foot yam – maize – greengram | (0.42 + 0.16 + 0) | : 0.58 |
| 3. Elephant-foot yam – mustard-sesame | (0.36 + 0.12 + 1.0) | : 0.58 |
| 4. Olitorius jute-greengram-potato-sesame | (0.12 + 0 + 0.48 + 0.10) | : 0.70 |
| 5. Olitorius jute-rice-rice | (0.12 + 0 + 0.80) | : 0.92 |
| 6. Elephant-foot yam-wheat-groundnut | (0.30 + 0.16 +0.15) | : 0.61 |
| 7. Greengram-rice-mustard | (0 + 0 + 0.12) | : 0.12 |
| 8. Green manure-rice-rice | (0 + 0 + 1.2) | : 1.20 |
| 9. Maize (greengram as inter crop)-greengram-potato | (0.15 + 0 + 0.48) | : 0.63 |
| 10. Elephant-foot yam (cowpea as intercrop)-maize-greengram | (0.42 +0.16 + 0) | : 0.58 |

### 3.6.6 Cultivation practices

Various crops were grown with their normal cultivation practices as usual. Very few plant protection measures were taken. Crops were subjected to irrigation with water containing arsenic (0.22 – 0.23 mg $l^{-1}$ of water). The sowing and harvesting dates of crops are given in Table 3.4.

## 3.7 Sampling technique

Sampling technique was divided into three categories as under:

(a) Agronomic observations for the study of plant characters at pre-harvest and post harvest stages.

(b) Soil sampling for the study of physical and chemical properties of the soil, and

(c) Plant material sampling for chemical analyses.

### 3.7.1 Sampling for agronomic observations

The technique of random sampling was adopted to study various plant characters leaving aside a width of about 1.5 to 2.0 m border around the plots. To study various plant characters, all observations were taken from the randomly selected row length (area inside border left aside) which was demarcated by pegs in all the crops. The observations were taken from 10 randomly selected plants within the demarcated area.

For destructive sampling, five plants were uprooted from each plot at different intervals according to the growth stages of the crops. For obtaining post harvest data, plants within 1 sq m area previously peg-marked, were harvested one day before total harvest from the entire field. For estimation of grain and straw yields, crops were harvested leaving the border area.

### 3.7.2 Soil sampling

Soil samples were collected from 4-5 points of each plot with the help of a spiral auger, at a depth of 0-15 cm. Samples were collected from each plot twice: once before and the other after harvest of each crop in all the sequences. The samples collected were composited and mixed thoroughly, air dried, ground and stored properly in bags. Ground soils were passed through a 100-mesh sieve, required amount of soils were then taken and chemical analyses were done.

**TABLE 3.4**

**Date of sowing and date of harvesting of the crops in different cropping sequences**

| Cropping sequence | Date of sowing | | | Date of harvesting | | |
|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-2001 | 1998-99 | 1999-2000 | 2000-2001 |
| 1. M-G-P | | | | | | |
| M | 08.03.98 | 06.03.99 | 10.03.00 | 15.06.98 | 17.06.99 | 30.06.00 |
| G | 06.07.98 | 20.07.99 | 15.07.00 | 10.09.98 | 30.09.99 | 20.09.00 |
| P | 24.10.98 | 24.10.99 | 29.10.00 | 17.02.99 | 28.02.00 | 05.02.01 |
| 2.E-M-G | | | | | | |
| E | 16.04.98 | 05.05.99 | 10.05.00 | 12.09.98 | 14.09.99 | 28.09.00 |
| M | 23.10.98 | 03.11.98 | 14.11.00 | 20.01.99 | 10.01.00 | 21.01.01 |
| G | 15.02.99 | 10.02.99 | 28.02.01 | 20.04.99 | 17.04.00 | 3.04.01 |
| 3. E-Md-S | | | | | | |
| E | 06.05.98 | 02.05.99 | 09.05.00 | 14.09.98 | 12.09.99 | 14.10.00 |
| Md | 07.11.98 | 17.11.99 | 23.11.00 | 22.02.99 | 03.02.99 | 21.02.01 |
| S | 28.02.99 | 21.02.99 | 05.03.01 | 14.04.99 | 21.04.00 | 07.05.01 |
| 4. Jo-G-P-S | | | | | | |
| Jo | 05.05.98 | 10.05.99 | 11.05.00 | 20.08.98 | 11.08.99 | 26.08.00 |
| G | 02.09.98 | 02.09.99 | 05.09.00 | 25.10.98 | 02.01.99 | 11.11.00 |
| P | 09.11.98 | 13.11.99 | 21.11.00 | 05.02.99 | 07.01.99 | 10.02.01 |
| S | 20.02.99 | 24.02.00 | 28.02.01 | 02.05.99 | 29.05.00 | 04.06.01 |
| 5. Jo-Ra-Rb | | | | | | |
| Jo | 10.05.98 | 17.05.99 | 19.05.00 | 04.08.98 | 02.08.99 | 12.08.00 |
| Ra | 22.08.98 | 26.08.99 | 29.08.00 | 01.12.98 | 17.12.99 | 18.12.00 |
| Rb | 07.01.99 | 11.01.00 | 10.01.01 | 12.04.99 | 21.04.00 | 29.04.01 |
| 6. E-W-Gn | | | | | | |
| E | 01.06.98 | 21.06.99 | 04.07.00 | 17.10.98 | 30.10.99 | 12.11.00 |
| W | 20.11.98 | 25.11.99 | 29.11.00 | 13.02.99 | 28.02.00 | 27.02.01 |
| Gn | 27.02.99 | 24.02.00 | 05.03.01 | 07.06.99 | 20.06.00 | 30.06.01 |
| 7. G-Ra-Md | | | | | | |
| G | 10.03.98 | 19.03.99 | 15.03.00 | 15.05.98 | 22.05.99 | 24.05.00 |
| Ra | 13.07.98 | 14.07.99 | 10.07.00 | 17.10.98 | 20.10.99 | 28.10.00 |
| Md | 09.11.98 | 14.11.99 | 20.11.00 | 23.02.99 | 28.02.00 | 02.03.01 |
| 8. Gm-Ra-Rb | | | | | | |
| Gm | 10.05.98 | 21.05.99 | 28.05.00 | 23.06.98 | 26.07.99 | 21.07.00 |
| Ra | 30.07.98 | 02.08.99 | 10.08.00 | 27.11.98 | 04.12.99 | 14.12.00 |
| Rb | 11.01.99 | 17.01.00 | 19.01.01 | 19.04.99 | 24.04.00 | 29.04.01 |
| 9. M(Gi)-G-P | | | | | | |
| M | 10.03.98 | 22.03.99 | 12.03.00 | 17.06.98 | 29.06.99 | 30.06.00 |
| Gi | 20.04.98 | 24.04.99 | 27.03.00 | 16.06.98 | 21.06.99 | 29.05.00 |
| G | 08.08.98 | 13.08.99 | 19.07.00 | 20.10.98 | 12.10.99 | 22.09.00 |
| P | 24.10.98 | 29.10.99 | 29.10.00 | 19.02.99 | 05.03.00 | 11.02.01 |
| 10. E(Ci)-M-G | | | | | | |
| E | 16.04.98 | 10.05.99 | 10.05.00 | 14.09.98 | 19.09.99 | 30.09.00 |
| Ci | 21.04.98 | 28.05.99 | 17.05.00 | 26.06.98 | 28.07.99 | 19.06.00 |
| M | 23.10.98 | 29.10.99 | 04.11.00 | 22.01.98 | 26.01.00 | 21.01.01 |
| G | 15.02.99 | 19.02.00 | 28.02.01 | 26.04.99 | 30.04.00 | 36.05.01 |

Note: M = Maize; G = Greengram; W = Wheat; P = Potato; Gn = Groundnut; E = Elephant-foot yam; Gm = Green manure; Md = Mustard; (Gi) = Greengram as intercrop; S = sesame; (Ci) = Cowpea as intercrop; Jo = Olitorius jute; Rb = Rice (summer/*boro*) and Ra = Rice (winter/*aman*)

### 3.7.3 Plant material sampling

The samples harvested were used as plant sample materials for the determination of total nitrogen, phosphorus, potassium and arsenic after drying and grinding. The plant samples taken from crop sample harvests, were kept in paper packets and placed in oven at a temperature of 80 ± 1 $^0$C for 6 - 8 hours for 2 days. The dried materials were then properly powdered using a grinder.

## 3.8 Agronomic observations

### 3.8.1 Pre-harvest observations

#### 3.8.1.1 Growth study

It was done from ten randomly selected plants, previously peg-marked, from each replication in different intervals according to the stages of crop growth. Observations were recorded in rice and wheat beginning with 4 weeks after transplanting in rice and 4 weeks after sowing in wheat and from the onset of reproductive primordia at an interval of 2 or 3 weeks in other crops; in jute, beginning with 1 month after sowing at an interval of 2 weeks; in elephant-foot yam, starting from 6 weeks after emergence at an interval of 4 weeks and in potato, from tuberisation at an interval of 3 weeks.

#### 3.8.1.2 Dry weight of plants

Five plants were taken at a time randomly from the field, washed properly and dried in a hot air oven at 80 – 90 $^0$C for 8 - 10 hours, cooled and weighed and the data was converted to g $m^{-2}$. Samples were taken at the intervals mentioned earlier.

#### 3.8.1.3 Leaf area index (LAI)

It was calculated on area-weight relationship. Ten leaves were selected at random from the plant sample and those leaves were cut into rectangular/circular shape of finite (known) area. The latter were dried in an oven and the dry weight was measured. By using these area-weight relation, the LAI of crop plants were calculated.

#### 3.8.1.4 Crop growth rate (CGR)

It represents the gain in dry weight, as recorded over an interval of crop growth, by an unit area under the given crop in unit time, and is expressed as g $m^{-2}$ $d^{-1}$. It was calculated by using the following formula:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \quad g\ m^{-2}\ d^{-1}$$

Where, $W_1$ and $W_2$ were the plant dry weights at time $t_1$ and $t_2$, respectively.

### 3.8.2 Post-harvest observations

#### 3.8.2.1 Grain/seed/corm/tuber/fibre yield

Yield data were taken from the demarcated area of the field. Hand picking was done in case of greengram while cobs were separated and collected in case of maize. Groundnut, potato and elephant-foot yam were harvested by digging and the respective yields of pod, tuber and corm were taken. In case of other crops, plants were cut to the base and then seed/grain/pod were separated, dried and weighed. Yields thus obtained from each plot was converted into hectare basis. In case of jute, after retting and subsequent drying, the fibre yield was recorded.

#### 3.8.2.2 Straw/stalk/stover yield

After separating the seeds/grains/pods/cobs, etc. the plants were subjected to drying in the sun to attain a constant weight. These were weighed and the values obtained were converted into hectare basis.

#### 3.8.2.3 Harvest index (HI)

Harvest index was calculated by the following formula:

$$HI = \frac{\text{Economic yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

## 3.9 Other observations

### 3.9.1 Nodulation studies (in groundnut, greengram and green manure)

Five plants were selected and uprooted randomly from each plot. Lower portions of the plants were washed in clean water and the number of effective and ineffective nodules were counted for each plant and average number was recorded.

Difference between effective and ineffective nodules was made by cutting the nodules with a blade. Effective nodules showed pink coloured pith while blackish pith was associated with ineffective nodules.

### 3.9.2 Root studies

#### 3.9.2.1 Volume of root

Five plants were randomly selected and dug out carefully. Roots were then washed and dipped in a container completely full of water. The displaced water, made by root dipping was measured in a measuring cylinder. The volume of displaced water was equal to the volume of root. Then the average value of volume of roots for each plant was recorded.

#### 3.9.2.2 Dry weight of root

Five plants were randomly dug out from each plot. The roots were then thoroughly washed in water and placed in a hot-air oven at a temperature of 90 $^0$C for 10 hours till it attained the constant weight. Then the average value from the dry weight of five plant roots was recorded.

## 3.10 Soil chemical analyses

### 3.10.1 Total nitrogen (N) content in soil

Total nitrogen content of soil was determined in percentage according to modified Kjeldahl method as described by Jackson (1967).

### 3.10.2 Available phosphorus (P) content in soil

It was determined in kg ha$^{-1}$ according to Olsen's method, as described by Jackson (1967).

### 3.10.3 Available potassium (K) content in soil

Available potash in kg ha$^{-1}$ was determined flamephotometrically (Jackson, 1967) using ammonium acetate as extractant.

### 3.10.4 Soil pH

pH was determined by using soil suspension in water at the ratio of 1 : 2.5 (Jackson, 1967) and a glass electrode pH meter.

### 3.10.5 Olsen-extractable arsenic content of soil

Olsen's reagent (0.5 M $NaHCO_3$, pH 8.5) was used for extraction of available arsenic from soil. Each soil solution (1 : 20) mixture was shaken for a period of 2 hours, thereafter filtered through a Whatman No. 42 filter paper. Arsenic in the extract was determined by Atomic Absorption Spectrophotometer (AAS), coupled with a hydride generator unit, employing arsine generation.

## 3.11 Plant chemical analyses

Plant analytical works were done for determination of nitrogen, phosphorus and potassium contents in plant materials. All calculations were done on dry weight basis.

### 3.11.1 Total nitrogen

Total nitrogen content in plant material was determined in percentage, according to modified Kjeldahl method as described by Jackson (1967).

### 3.11.2 Phosphorus

Percentage of phosphorus content of the material was determined after wet digestion (Jackson, 1967).

### 3.11.3 Potassium

Potassium content in percentage was determined after wet digestion using flame photometric method (Jackson, 1967).

### 3.11.4 Arsenic

Plant samples collected at various growth stages were dried in hot-air oven at 80 $^0$C and then ground. Those were then digested with 20 ml of tri-acid mixture ($HNO_3$ : $H_2SO_4$ : $HCl_4$ :: 10 : 1 : 4, by volume), and then the arsenic content in the digest was measured by the use of the Atomic Absorption Spectrophotometer coupled with the hydride generator unit.

### 3.11.5 Uptake of nutrients by crops

Concentration of different nutrients in plants were determined on dry weight basis following methods described earlier wherefrom the uptake of nutrients in kg $ha^{-1}$ was calculated as:

$$\text{Uptake (kg ha}^{-1}) = \text{Concentration (\%)} \times \text{total dry weight (kg ha}^{-1}) \times 100$$

## 3.12 Methods of analyses of data

Statistical analyses of the data and interpretations were made in accordance with Fisher's method of analysis of variance for two-way classified data with one observation per cell (Fisher, 1938). The calculated values of 'F's were tested at 5% level of significance and simultaneously CD values were calculated for above level of significance for ascertaining the significance of findings. For analysing the data of individual crop parameters, within different systems of cropping, the Fisher's method of analysis of variance for one-way classified data had been followed. Inferences were drawn at 5% level of significance. When the number of treatments was only two, for testing whether the average effects of treatments were same or not, the Student's 't' test for equality of two means had been followed.

## 3.13 Economic analyses

### 3.13.1 Total cost of cultivation

It was calculated crop-wise on the basis of prevailing local rates for various inputs of cropping.

### 3.13.2 Gross return

Gross return was calculated based on the prevailing selling price of different produces of the crops.

### 3.13.3 Benefit : cost ratio

Benefit : cost ratio was calculated by dividing the gross return obtained by the corresponding cost of cultivation.

### 3.13.4 Input prices, selling prices and labour expenditure

#### 3.13.4.1 Cost of seed

| Crop | Value (Rs $ha^{-1}$) |
|---|---|
| Rice | 12.00 |
| Potato | 6.50 |
| Maize | 35.00 |
| Greengram | 20.00 |
| Groundnut | 21.00 |
| Mustard | 15.00 |
| Jute | 45.00 |
| Sesame | 25.00 |
| Elephant-foot yam | 6.00 |
| Cowpea | 10.00 |
| Wheat | 10.00 |

#### 3.13.4.2 Cost of fertilizers

(a) Nitrogenous fertilizer (urea) Rs 4.60 per kg

(b) Phosphatic fertilizer (SSP) Rs 3.20 per kg

(c) Potassic fertilizer (MOP) Rs 4.25 per kg

#### 3.13.4.3 Miscellaneous cost

(a) Bullock pair Rs 60.00/day

(b) Labour wage Rs 40.00/man/day

#### 3.13.4.4 Cost of irrigation*

| Crop | Value (Rs $ha^{-1}$) |
|---|---|
| Rice: Winter/*aman* | 180.00 |
| Summer/*boro* | 720.00 |
| Potato | 100.00 |
| Jute | 180.00 |
| Wheat | 90.00 |
| Mustard | 180.00 |
| Groundnut | 300.00 |
| Maize: *Rabi* | 90.00 |
| *Kharif* | 100.00 |
| Sesame | 100.00 |
| Elephant-foot yam | 300.00 |
| Greengram | 100.00 |

* Water revenue $crop^{-1}$ covering the entire season at Government rate.

### 3.13.4.5 Price of economic products (selling price)

| Crop | Value (Rs $kg^{-1}$) |
|---|---|
| Rice | 7.00 |
| Jute (fibre) | 8.00 |
| Mustard | 10.00 |
| Sesame | 14.00 |
| Groundnut | 15.00 |
| Wheat | 4.00 |
| Greengram | 10.00 |
| Elephant-foot yam | 4.00 (for 1st year) |
| | 3.00 (for last 2 years) |
| Maize | 3.00 |
| Potato | 2.50 |

# Chapter 4

# RESULTS AND DISCUSSION

# 4. RESULTS AND DISCUSSION

The experiment on different systems of cropping, to study on various aspects of arsenic towards growth and yield of crops as well as the build-up of arsenic in soil-plant system, was conducted for three consecutive years (1998-1999, 1999-2000 and 2000-2001). The observations recorded were statistically analysed, presented and properly discussed in the following sections:

## 4.1 Growth studies

No visual phytotoxic effect of arsenic was noted on any of the crops tried and plant growth remained unaffected.

### 4.1.1 Leaf area index (LAI) of crops in different systems of cropping

#### 4.1.1.1 LAI of greengram

Results presented in Table 4.1 showed increase in LAI of greengram in different systems of cropping upto 45 DAS when the value was highest and thereafter it declined at 60 DAS in all the three years of cropping. LAI of greengram was lowest at 60 DAS in all cases due to leaf senescence and attainment towards maturity.

In both 1$^{st}$ and 2$^{nd}$ year, significant variation in LAI of greengram was noted only at 45 DAS. However, growing greengram with different systems of cropping did not show any variation in 3$^{rd}$ year.

Greengram, grown after jute in sequence 4 (Jo-G-P-S), showed the highest LAI at all the dates of recording observations during all the three years of cropping which might be due to better availability of soil moisture after monsoon alongwith greater availability of nutrients particularly N after cultivation of jute. Greengram, grown after maize in sequence 1 (M-G-P), recorded higher values of LAI in 1$^{st}$ year. Intercropping greengram with maize (sequence 9) showed lower LAI values in all the three years of cropping due to greater competition for growth resources such as sunlight, soil moisture and nutrients by the main crop of maize.

#### 4.1.1.2 LAI of potato

Potato, grown in different sequences, recorded highest LAI values at 60 DAS and thereafter it gradually declined reaching the lowest values at 100 DAS in all the years of experimentation (Table 4.2). The lowest values of LAI, at 100 DAS, were due to senescence of leaves at that stage. Variations were noted towards LAI of potato with different systems of cropping in all the dates of recording observation during both 1st and 2nd year of experimentation. But growing potato in different systems of cropping showed no variation with respect to LAI values at 40 and at 80 DAS in 3rd year.

In 1st year, the highest LAI of 3.95 was noted at 60 DAS in sequence 9 [M(Gi)-G-P] which was at par with the LAI in sequence 4. LAI of potato grown in sequence 1 (M-G-P) was lowest at that stage compared with the sequences 4 and 9. In 2nd year, the highest LAI value of 4.00 was obtained in sequence 4. The same trend was obtained in the 3rd year also. Potato, grown after greengram in sequence 9, recorded the highest values of LAI at 60, 80 and at 100 DAS in 1st year, which resulted from the beneficial effect of legume. Bhunia *et al.* (1997b) found similar type of observation.

#### 4.1.1.3 LAI of rice

Rice showed gradual increase in LAI values upto 60 DAT and thereafter it declined (Table 4.3). Growing rice in different sequences during *kharif* and *boro* seasons did not show much variation in LAI values at any of the dates of taking observation.

Among the winter rice crops, the crop grown in sequence 8 after incorporation of green manure showed higher LAI values in all the three years of experimentation which was closely followed when this crop was raised after jute in sequence 5. The highest LAI values of 3.26, 3.40 and 3.31 were noted at 60 DAT in sequence 8 in 1st, 2nd and 3rd year, respectively.

*Boro* or summer rice grown in sequence 8 showed higher LAI values at all the dates of taking observation in all the three years of cropping than in sequence 5. The highest LAI values of 3.73, 3.89 and 3.94 were noted at 60 DAT in sequence 8. Summer rice grown in different sequences showed significantly higher LAI values than winter rice at almost all the growth stages. Higher LAI values in both winter and summer rices, grown after the incorporation of green manure, in comparison with rice grown with other sequences thereby showing beneficial effect of green manuring on the succeeding crop. Mandal *et al.* (1992) found similar beneficial effect of green leaf manuring on rice.

#### 4.1.1.4 LAI of maize

It was evident that LAI of maize increased upto 75 DAS as the growth progressed in all the three years of cropping (Table 4.4). The highest LAI was noted at 75 DAS. Significant variation was noted with respect to LAI of maize in all the growth stages studied and during all the three years of investigation.

Summer maize, grown after potato in sequence 9, recorded the highest LAI of 3.56, 3.82 and 3.98 in $1^{st}$, $2^{nd}$ and $3^{rd}$ year, respectively, at 75 DAS closely followed by maize in sequence 1. Significant variation in LAI values at 75 DAS between sequence 9 and 1 was noted in $3^{rd}$ year only.

Maize, grown in winter in sequences 2 and 10, showed lower LAI values than summer maize in sequences 9 and 1. Winter maize grown in sequence 10 showed higher LAI in most of the growth stages.

Higher LAI recorded in summer maize in sequences 1 and 9 compared with winter maize in sequences 2 and 10 during all the three years of experimentation suggested better growth occurred in summer; poor growth in winter maize was resulted from low temperature and less sunshine hours.

Inclusion of greengram as intercrop with maize in sequence 9 showed higher values of LAI than sole maize in sequence 1. Maize grown after elephant-foot yam intercropped with cowpea showed slightly higher LAI values than grown after sole elephant-foot yam in sequence 2. In both the cases, beneficial effect of intercrop was observed.

#### 4.1.1.5 LAI of jute

No significant variation towards the LAI of jute, grown in different cropping sequences was noticed at any stage of growth during all the three years of investigation (Table 4.5). However, jute grown after *boro*/summer rice, in sequence 5, showed an increasing trend in LAI at all the growth stages compared with jute grown after sesame in sequence 4.

Jute showed increase in LAI upto 75 DAS followed by slight decrease at 90 DAS. The highest LAI values of 3.01, 3.12 and 3.21 were noted at 75 DAS in sequence 5 during $1^{st}$, $2^{nd}$ and $3^{rd}$ year, respectively.

#### 4.1.1.6 LAI of mustard

There was no variation towards the LAI of mustard grown with two different systems of cropping at any stage (Table 4.6). Mustard recorded the highest LAI at 60 DAS and thereafter it declined with the progress of growth. It recorded the highest LAI of 2.87 and 2.91 at 60 DAS in sequence 3 during $1^{st}$ and $3^{rd}$ year, respectively. While in $2^{nd}$ year, the highest LAI (2.79) was recorded at 60 DAS in sequence 7. Preceding crop seemed to exert little influence on the growth of succeeding mustard as was evident from little variation in LAI.

#### 4.1.1.7 LAI of sesame

Growing sesame in various systems of cropping seemed to have no effect on it's LAI (Table 4.7). Sesame, grown after potato in sequence 4, showed slightly higher values of LAI in most of the stages studied. In general, sesame showed gradual increase in LAI upto 60 DAS and declined thereafter. The highest LAI values of 1.64, 1.84 and 1.89 were noted at 60 DAS in sequence 4 during $1^{st}$, $2^{nd}$ and $3^{rd}$ year of experimentation, respectively. The residual effect of high dose of fertilizer given to potato might had resulted higher growth and LAI in the succeeding crop of sesame.

#### 4.1.1.8 LAI of groundnut

The results showed gradual increase in LAI of groundnut upto 75 DAS (Table 4.8). In $1^{st}$ year, the highest LAI of 3.54 was noted at 75 DAS and the highest values of 3.72 and 3.88 were noted at the same stage in $2^{nd}$ and $3^{rd}$ year of investigation, respectively.

#### 4.1.1.9 LAI of wheat

Wheat showed gradual increase in LAI upto 60 DAS which then declined at 75 DAS due to the senescence of leaves (Table 4.9). It showed the highest value at 60 DAS in all the three years of experimentation.

#### 4.1.1.10 LAI of elephant-foot yam

LAI of elephant-foot yam showed gradual increase with the progress of growth upto 120 DAS and thereafter declined at 150 DAS (Table 4.10). Growing elephant-foot yam in different systems of cropping showed no variation in LAI at 60 and at 150 DAS in $1^{st}$ year while variation was noted at 90 and at 120 DAS. Variation in LAI of elephant-foot yam grown in different sequences was noted during all the stages of growth save at 150 DAS in $2^{nd}$ year while it showed significant variation at all the stages of $3^{rd}$ year except at 60 DAS.

Elephant-foot yam recorded the highest LAI (3.83) in sequence 6 at 120 DAS in $1^{st}$ year while the highest values of 4.41 and 4.59, respectively, were recorded in sequence 3 at the same stage in $2^{nd}$ and $3^{rd}$ years of investigation. Growing cowpea as an intercrop with elephant-foot yam recorded relatively lower LAI values during all the three years of experimentation which might be due to competition for growth resources between the component crops. Lower LAI at all the growth stages with all the sequences in $1^{st}$ year was due to lower growth of the crop owing to the use of low seed size.

### 4.1.2 Dry matter (DM) accumulation of crops in different systems of cropping (g $m^{-2}$)

#### 4.1.2.1 DM accumulation of greengram

An increasing trend towards the accumulation of DM in greengram was observed from 30 to 60 DAS in all the three years of experimentation (Table 4.11). Rate of increase in DM was more during 30 – 45 DAS; but it varied with different systems of cropping. Variation in DM accumulation was noted at all the growth stages

# TABLE 4.1

## LAI of greengram with different systems of cropping

| Cropping sequence | LAI | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS |
| 1. M-G-P | 1.32 | 3.14 | 1.12 | 1.07 | 2.72 | 1.00 | 1.13 | 3.01 | 1.09 |
| 2. E-M-G | 1.07 | 2.76 | 1.01 | 1.12 | 2.86 | 0.87 | 1.24 | 3.22 | 1.02 |
| 4. Jo-G-P-S | 1.42 | 3.28 | 1.21 | 1.21 | 3.07 | 1.12 | 1.30 | 3.31 | 1.17 |
| 7. G-Ra-Md | 1.03 | 2.86 | 1.04 | 0.93 | 2.95 | 0.72 | 1.23 | 3.11 | 1.14 |
| 9. M(Gi)-G-P | *(0.86) | (1.63) | (0.72) | (0.81) | (1.42) | (0.62) | (1.03) | (2.65) | (0.94) |
| | 1.27 | 3.10 | 1.20 | 1.13 | 2.80 | 1.03 | 1.19 | 3.17 | 1.12 |
| 10. E(Ci)-M-G | 1.14 | 2.93 | 0.98 | 1.08 | 2.95 | 0.93 | 1.17 | 3.10 | 0.97 |
| SEm (±) | 0.20 | 0.31 | 0.20 | 0.21 | 0.24 | 0.19 | 0.26 | 0.34 | 0.20 |
| CD at 5% | NS | 0.95 | NS | NS | 0.73 | NS | NS | NS | NS |

* Intercrop value

# TABLE 4.2

## LAI of potato with different systems of cropping

| Cropping sequence | LAI | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 40 DAS | 60 DAS | 80 DAS | 100 DAS | 40 DAS | 60 DAS | 80 DAS | 100 DAS | 40 DAS | 60 DAS | 80 DAS | 100 DAS |
| 1. M-G-P | 1.20 | 3.48 | 2.49 | 1.04 | 1.28 | 3.62 | 2.71 | 1.24 | 1.42 | 4.10 | 2.79 | 1.08 |
| 4. Jo-G-P-S | 1.42 | 3.88 | 2.65 | 1.21 | 1.30 | 4.00 | 2.54 | 1.17 | 1.43 | 4.26 | 2.85 | 1.31 |
| 9. M(Gi)-G-P | 1.30 | 3.95 | 2.71 | 1.27 | 1.22 | 3.92 | 2.83 | 1.09 | 1.36 | 4.03 | 2.80 | 1.21 |
| SEm (±) | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 | 0.04 | 0.04 | 0.04 |
| CD at 5% | 0.07 | 0.11 | 0.07 | 0.07 | 0.11 | 0.07 | 0.11 | 0.11 | NS | 0.15 | NS | 0.15 |

## TABLE 4.3

### LAI of rice with different systems of cropping

| Cropping sequence | LAI | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | 30 DAT | 45 DAT | 60 DAT | 75 DAT | 30 DAT | 45 DAT | 60 DAT | 75 DAT |
| ✪ *Aman* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 1.79 | 2.10 | 3.24 | 0.68 | 1.67 | 2.32 | 3.38 | 0.93 | 1.59 | 2.22 | 3.12 | 0.83 |
| 7. G-Ra-Md | 1.70 | 2.04 | 3.18 | 0.79 | 1.58 | 2.12 | 3.30 | 1.06 | 1.43 | 2.28 | 3.21 | 0.92 |
| 8. Gm-Ra-Rb | 1.83 | 2.30 | 3.26 | 0.98 | 1.74 | 2.43 | 3.40 | 1.14 | 1.73 | 2.31 | 3.31 | 1.03 |
| ✪ *Boro* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 2.02 | 2.59 | 3.68 | 1.17 | 2.20 | 2.63 | 3.59 | 1.20 | 2.43 | 2.97 | 3.47 | 1.08 |
| 8. Gm-Ra-Rb | 2.23 | 2.93 | 3.73 | 1.24 | 2.42 | 3.06 | 3.89 | 1.32 | 2.63 | 3.08 | 3.94 | 1.12 |
| SEm (±) | 0.043 | 0.060 | 0.040 | 0.043 | 0.052 | 0.064 | 0.076 | 0.046 | 0.059 | 0.047 | 0.061 | 0.040 |
| CD at 5% | 0.140 | 0.195 | 0.130 | 0.140 | 0.169 | 0.208 | 0.228 | 0.150 | 0.192 | 0.153 | 0.198 | 0.130 |

## TABLE 4.4

### LAI of maize with different systems of cropping

| Cropping sequence | LAI | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
| 1. M-G-P | 0.60 | 1.23 | 2.76 | 3.45 | 0.78 | 1.83 | 2.87 | 3.73 | 1.10 | 2.09 | 2.92 | 3.85 |
| 2. E-M-G | 0.41 | 1.07 | 1.78 | 2.10 | 0.53 | 1.29 | 1.68 | 2.52 | 0.64 | 1.41 | 1.83 | 2.69 |
| 9. M(Gi)-G-P | 0.65 | 1.31 | 2.65 | 3.56 | 0.83 | 1.95 | 2.96 | 3.82 | 1.17 | 2.19 | 3.04 | 3.98 |
| 10. E(Ci)-M-G | 0.47 | 1.25 | 1.90 | 2.43 | 0.58 | 1.45 | 2.39 | 2.66 | 0.78 | 1.53 | 2.13 | 2.71 |
| SEm (±) | 0.020 | 0.024 | 0.035 | 0.051 | 0.026 | 0.030 | 0.049 | 0.032 | 0.021 | 0.030 | 0.082 | 0.024 |
| CD at 5% | 0.06 | 0.08 | 0.12 | 0.17 | 0.08 | 0.10 | 0.16 | 0.11 | 0.07 | 0.10 | 0.28 | 0.08 |

## TABLE 4.5

### LAI of jute with different systems of cropping

| Cropping sequence | LAI | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | | 1999-2000 | | | | | 2000-2001 | | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| 4. Jo-G-P-S | 1.17 | 1.78 | 2.41 | 2.95 | 2.42 | 1.24 | 1.92 | 2.83 | 2.90 | 2.60 | 1.04 | 2.12 | 2.73 | 3.04 | 2.41 |
| 5. Jo-Ra-Rb | 1.30 | 2.10 | 2.78 | 3.01 | 2.57 | 1.37 | 2.07 | 2.91 | 3.12 | 2.61 | 1.23 | 2.05 | 2.85 | 3.21 | 2.83 |
| 't' value | 2.85$^{NS}$ | 1.44$^{NS}$ | 8.13$^{NS}$ | 1.31$^{NS}$ | 3.29$^{NS}$ | 2.85$^{NS}$ | 3.29$^{NS}$ | 1.75$^{NS}$ | 4.83$^{NS}$ | 1.30$^{NS}$ | 4.17$^{NS}$ | 1.53$^{NS}$ | 2.63$^{NS}$ | 3.73$^{NS}$ | 1.21$^{NS}$ |

## TABLE 4.6

### LAI of mustard with different systems of cropping

| Cropping sequence | LAI | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| 3. E-Md-S | 1.62 | 2.87 | 1.84 | 1.52 | 1.59 | 2.62 | 1.98 | 1.64 | 1.70 | 2.91 | 2.18 | 1.73 |
| 7. G-Ra-Md | 1.54 | 2.74 | 2.10 | 1.63 | 1.74 | 2.79 | 2.24 | 1.75 | 1.62 | 2.61 | 1.93 | 1.59 |
| 't' value | 1.75$^{NS}$ | 2.85$^{NS}$ | 3.51$^{NS}$ | 2.41$^{NS}$ | 3.20$^{NS}$ | 3.73$^{NS}$ | 1.69$^{NS}$ | 2.41$^{NS}$ | 1.75$^{NS}$ | 6.59$^{NS}$ | 5.49$^{NS}$ | 3.07$^{NS}$ |

## TABLE 4.7

### LAI of sesame with different systems of cropping

| Cropping sequence | LAI | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 45 DAS | 60 DAS | 75 DAS | 45 DAS | 60 DAS | 75 DAS | 45 DAS | 60 DAS | 75 DAS |
| 3. E-Md-S | 1.13 | 1.54 | 0.40 | 1.19 | 1.72 | 0.50 | 1.23 | 1.73 | 0.52 |
| 4. Jo-G-P-S | 1.19 | 1.64 | 0.48 | 1.26 | 1.84 | 0.42 | 1.32 | 1.89 | 0.67 |
| 't' value | 1.31$^{NS}$ | 2.19$^{NS}$ | 1.75$^{NS}$ | 1.53$^{NS}$ | 2.17$^{NS}$ | 1.75$^{NS}$ | 1.97$^{NS}$ | 3.51$^{NS}$ | 3.29$^{NS}$ |

## TABLE 4.8

## LAI of groundnut

| Cropping sequence | LAI | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
| 6. E-W-Gn | 0.42 | 1.38 | 3.29 | 3.54 | 0.54 | 1.47 | 3.19 | 3.72 | 0.59 | 1.54 | 3.39 | 3.88 |

## TABLE 4.9

## LAI of wheat

| Cropping sequence | LAI | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
| 6. E-W-Gn | 1.90 | 2.14 | 2.29 | 1.60 | 2.03 | 2.36 | 2.41 | 1.52 | 2.14 | 2.46 | 2.62 | 1.73 |

## TABLE 4.10

## LAI of elephant-foot yam with different systems of cropping

| Cropping sequence | LAI | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS |
| 2. E-M-G | 2.30 | 2.81 | 3.62 | 3.17 | 2.41 | 3.19 | 4.31 | 3.81 | 2.23 | 3.42 | 4.31 | 3.93 |
| 3. E-Md-S | 2.24 | 2.63 | 3.45 | 3.22 | 2.34 | 3.47 | 4.41 | 3.92 | 2.41 | 3.57 | 4.59 | 4.12 |
| 6. E-W-Gn | 2.36 | 2.92 | 3.83 | 3.32 | 2.48 | 3.29 | 4.22 | 3.71 | 2.32 | 3.15 | 4.27 | 3.79 |
| 10. E(Ci)-M-G | 2.18 | 2.74 | 3.41 | 3.17 | 2.30 | 3.08 | 4.16 | 3.63 | 2.10 | 3.29 | 4.40 | 3.58 |
| SEm (±) | 0.054 | 0.045 | 0.084 | 0.091 | 0.040 | 0.039 | 0.062 | 0.080 | 0.095 | 0.040 | 0.031 | 0.100 |
| CD at 5% | NS | 0.150 | 0.290 | NS | 0.130 | 0.130 | 0.210 | NS | NS | 0.130 | 0.107 | 0.340 |

Plate 1 : Teachers and farmers in front of the crop cafeteria at Gotera

Plate 2 : Greengram at 30 DAS in sequence 7 (1999-2000)

studied in all the three years of experimentation. That variation might had resulted from the differences in temperature and rainfall prevailing during the growing season of greengram with different systems of cropping.

Greengram, grown after jute in sequence 4, recorded higher DM at all the growth stages during 1st year. But in later two years of investigation, no single sequence showed higher DM accumulation. Greengram, grown in sequence 4, recorded the highest DM yield at 60 DAS (372.4 and 382.1 g $m^{-2}$) in 2nd and 3rd year which was higher than greengram grown in any other sequence. Lower DM yield was noted in intercropped greengram (sequence 9).

Systems of cropping was found to result variation in DM accumulation of greengram. Higher DM accumulation in sequence 4 might had resulted from the increase in available nutrient status after cultivation of jute while lower DM yield in intercropped greengram might be possible due to competition between the components crops. Very high uptake of nutrients by maize might had caused reduction in soil fertility status resulting in poor growth and DM accumulation in the preceding greengram in sequence.

**4.1.2.2 DM accumulation of potato**

In general, potato recorded an increasing trend of DM accumulation as the growth progressed (Table 4.12). The extent of increase was more during 60 – 80 DAS. Variation was noted towards accumulation of DM by potato tried with different systems of cropping at all the dates of taking observation.

The highest DM accumulation to the tune of 592 g $m^{-2}$ of potato was noted with sequence 1 in 1st year, 605 g $m^{-2}$ in sequence 9 during 2nd year and 600 g $m^{-2}$ in sequence 4 in 3rd year at 100 DAS; no particular system of cropping showed superiority to others regarding accumulation of DM by potato. The variation in DM accumulation by potato during the years of experimentation might be due to better management in one compared with the others.

**4.1.2.3 DM accumulation of rice**

An increasing trend towards the accumulation of DM in both winter and summer rices were observed between 30 and 75 DAT in all the three years of investigation (Table 4.13). It became apparent that the differences in DM accumulation among the rice crops grown in various sequences during both the seasons were significant. DM accumulation was more in summer than in winter rice.

*Aman*/winter rice grown in sequence 8 after the incorporation of green manure resulted higher DM accumulation in most of the dates of recording observation during all the three years of investigation. *Boro*/summer rice grown after *aman* rice in sequence 8 recorded higher DM accumulation in all the dates of recording observation than *boro* rice in sequence 5.

Significantly higher DM accumulation was recorded in *boro* rice than in *aman* rice due to better growth and higher photosynthesis in the former. Growing and incorporation of green manure gave rise to higher DM accumulations in succeeding *aman* and *boro* rices when grown in sequence. This showed the beneficial effect of green manuring on the following crop by increasing the availability of plant nutrients. Mandal *et al.* (1992) found similar response of green leaf manuring on rice.

#### 4.1.2.4 DM accumulation of maize

Amount of DM accumulated by maize at 30, 45 and at 75 DAS, during all the three years of investigation, resulted significant variation in different systems of cropping (Table 4.14). However, maize grown during summer in sequences 1 and 9 gave rise to significantly higher amount of DM production than maize grown in winter with sequences 2 and 10. By and large, maize showed increasing amounts of DM accumulation as the growth progressed with the greatest increase in DM between 45 – 60 DAS. Maize, grown in sequence 9, recorded higher DM accumulation at all the stages of growth during 1$^{st}$ and 3$^{rd}$ years while it resulted in higher DM accumulation at all the dates of recording observation, except at 75 DAS, in 2$^{nd}$ year as compared to maize grown in other sequences. Winter maize grown in sequence 10 resulted slightly higher DM accumulation in most of the dates of recording observation compared with sequence 2. Higher DM accumulation in summer maize crops compared with winter maize might be attributed to low temperature experienced by the latter during the early growth stages. Similar result was earlier reported by Gangwar and Kalra (1981) and Patra *et al.* (1999 and 2000).

**4.1.2.5 DM accumulation of jute**

DM accumulation by jute gradually increased with the progress of growth from 30 – 90 DAS (Table 4.15). The rate of increase of DM by jute was higher during 60 – 75 DAS in most cases. However, growing jute in different systems of cropping did not register much variation at all the dates of taking observation. The highest amount of DM was noted in sequence 5 at 90 DAS. Jute, raised after summer rice in sequence 5, recorded higher DM accumulation at all the dates of taking observation compared with DM accumulated by jute when succeeded sesame in sequence 4.

**4.1.2.6 DM accumulation of mustard**

Growing mustard in different systems of cropping did not result significant variation towards the amount of DM accumulated at all the dates of recording observation (Table 4.16). In general, an increase in DM accumulation by mustard was noted from 45 to 90 DAS with maximum gain in DM between 60 – 75 DAS. DM accumulation of 492 and 501 g $m^{-2}$ were noted at 90 DAS in sequence 3 in 1st and 3rd year, respectively, while in 2nd year, sequence 7 recorded DM accumulation of 513 g $m^{-2}$ on the same DAS. Residual effect of high amount of fertilizer given to elephant-foot yam might had resulted in higher growth and simultaneously DM accumulation by the succeeding crop of mustard.

**4.1.2.7 DM accumulation of sesame**

DM accumulated by sesame, grown in different sequences at 45, 60 and at 75 DAS, did not show any variation during all the three years of experimentation (Table 4.17). It showed gradual increase towards the amount of DM accumulation from 45 to 75 DAS with the maximum accumulation during 60 – 75 DAS. Although little variation in DM accumulation by sesame grown in different sequences was noted, yet sesame grown after potato in sequence 4 recorded an increasing trend at all the dates of taking observation.

**4.1.2.8 DM accumulation by groundnut**

Groundnut, grown in sequence 6, showed gradual increase in DM accumulation as the growth progressed (Table 4.18). The highest accumulation of DM was found at 75 DAS in all the three years of investigation.

#### 4.1.2.9 DM accumulation of wheat

Wheat showed progressive increase in DM accumulation with the progress of crop growth from 30 to 75 DAS. The highest DM was found at 75 DAS in all the three years of experimentation. Maximum increase in DM by wheat was noted during 45-60 DAS (Table 4.19).

#### 4.1.2.10 DM accumulation by elephant-foot yam

An increase in DM accumulation by elephant-foot yam in different systems of cropping was noted as the crop growth progressed from 60 to 150 DAS (Table 4.20). Growing elephant-foot yam in different systems of cropping significantly influenced DM accumulation at all the dates of recording observation. Elephant-foot yam, grown after groundnut in sequence 6, recorded the highest DM accumulation at all the growth stages in 1st year followed by it when grown in sequence 2. This crop, when succeeded sesame in sequence 3, recorded the highest amount of DM accumulation as compared to elephant-foot yam grown with other sequences during both 2nd and 3rd years of experimentation. Comparatively lower DM accumulation by elephant-foot yam in 1st year was resulted from poor growth owing to the use of smaller size of seed corm. This influence of seed size on growth and DM accumulation by elephant-foot yam was earlier reported by Sen *et al.* (1984).

### 4.1.3 Crop growth rate (CGR) of crops in different systems of cropping

#### 4.1.3.1 CGR of greengram

CGR of greengram was always found to be higher between 30-45 DAS in all the sequences during all the three years of investigation (Table 4.21). Higher DM accumulation between 30 and 45 DAS resulted higher CGR in that period. CGR was found to be very low during 45-60 DAS. Greengram grown as intercrop alongwith maize in sequence 9 showed lower CGR values as compared to the other sequences. Higher CGR was noted in sequences 1, 4 and 7 during 45-60 DAS.

#### 4.1.3.2 CGR of potato

Potato showed increase in CGR values upto 80 DAS and it declined later, *i.e.*, during 80 – 100 DAS. Potato, grown in sequence 9, initially showed lower CGR

## TABLE 4.11

**DM accumulation of greengram with different systems of cropping**

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS |
| 1. M-G-P | 112.32 | 304.62 | 360.74 | 110.71 | 303.42 | 348.71 | 103.12 | 305.70 | 343.29 |
| 2. E-M-G | 103.63 | 286.42 | 328.43 | 109.23 | 310.23 | 353.12 | 107.37 | 320.74 | 374.37 |
| 4. Jo-G-P-S | 121.47 | 315.63 | 382.35 | 98.74 | 307.42 | 372.45 | 106.32 | 321.12 | 382.10 |
| 7. G-Ra-Md | 101.72 | 293.47 | 343.17 | 101.79 | 302.55 | 356.77 | 110.83 | 313.17 | 362.17 |
| 9. M(Gi)-G-P | *(64.12) | (153.17) | (199.72) | (50.53) | (141.32) | (199.41) | (74.13) | (173.42) | (214.7) |
| | 109.41 | 306.34 | 352.23 | 102.32 | 294.43 | 342.71 | 101.11 | 269.19 | 329.18 |
| 10. E(Ci)-M-G | 101.24 | 280.13 | 311.79 | 105.43 | 307.49 | 362.62 | 100.89 | 306.84 | 363.80 |
| SEm (±) | 2.14 | 2.20 | 2.08 | 3.08 | 2.56 | 2.11 | 2.17 | 2.32 | 2.24 |
| CD at 5% | 6.59 | 6.78 | 6.40 | 6.40 | 7.88 | 6.50 | 6.69 | 7.14 | 6.90 |

* Intercrop value

## TABLE 4.12

**DM accumulation of potato with different systems of cropping**

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 40 DAS | 60 DAS | 80 DAS | 100 DAS | 40 DAS | 60 DAS | 80 DAS | 100 DAS | 40 DAS | 60 DAS | 80 DAS | 100 DAS |
| 1. M-G-P | 117.3 | 230.1 | 473.1 | 591.8 | 144.95 | 240.3 | 483.9 | 575.9 | 132.1 | 226.9 | 498.3 | 580.7 |
| 4. Jo-G-P-S | 124.2 | 227.3 | 462.4 | 561.0 | 129.31 | 238.8 | 470.2 | 560.3 | 143.2 | 261.3 | 483.7 | 600.0 |
| 9. M(Gi)-G-P | 121.8 | 210.2 | 456.9 | 572.3 | 132.56 | 226.9 | 498.4 | 605.2 | 129.0 | 239.5 | 482.1 | 592.2 |
| SEm (±) | 0.43 | 0.49 | 1.10 | 1.64 | 0.45 | 0.52 | 0.98 | 1.97 | 0.49 | 0.59 | 0.44 | 1.54 |
| CD at 5% | 1.69 | 1.92 | 4.31 | 4.63 | 1.76 | 2.04 | 3.84 | 7.73 | 1.92 | 2.31 | 1.72 | 6.04 |

## TABLE 4.13

**DM accumulation of rice with different systems of cropping**

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAT | 45 DAT | 60 DAT | 75 DAT | 30 DAT | 45 DAT | 60 DAT | 75 DAT | 30 DAT | 45 DAT | 60 DAT | 75 DAT |
| ✪ *Aman* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 152.7 | 302.7 | 519.7 | 629.7 | 170.1 | 323.7 | 501.7 | 632.6 | 201.3 | 312.7 | 499.3 | 631.7 |
| 7. G-Ra-Md | 141.3 | 291.9 | 493.2 | 641.7 | 162.5 | 312.5 | 500.9 | 622.5 | 170.5 | 301.8 | 510.4 | 657.3 |
| 8. Gm-Ra-Rb | 161.9 | 312.3 | 512.3 | 661.3 | 176.3 | 341.7 | 523.4 | 682.1 | 190.4 | 323.8 | 502.8 | 642.9 |
| ✪ *Boro* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 231.3 | 422.7 | 554.9 | 741.5 | 193.5 | 361.7 | 513.9 | 682.5 | 201.9 | 383.4 | 545.5 | 724.5 |
| 8. Gm-Ra-Rb | 240.7 | 431.4 | 582.7 | 761.3 | 201.7 | 383.5 | 541.2 | 694.8 | 225.4 | 401.8 | 560.4 | 747.9 |
| SEm (±) | 1.56 | 2.40 | 3.50 | 4.46 | 1.82 | 5.14 | 2.84 | 3.46 | 3.10 | 2.53 | 3.94 | 4.59 |
| CD at 5% | 5.08 | 7.82 | 11.41 | 14.54 | 5.93 | 16.76 | 9.26 | 11.28 | 10.10 | 8.25 | 12.84 | 14.96 |

## TABLE 4.14

**DM accumulation of maize with different systems of cropping**

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
| 1. M-G-P | 59.30 | 139.77 | 459.81 | 732.9 | 62.83 | 143.81 | 463.52 | 776.13 | 64.18 | 150.32 | 461.81 | 770.31 |
| 2. E-M-G | 32.93 | 86.64 | 309.91 | 469.9 | 37.68 | 89.42 | 312.76 | 487.34 | 39.10 | 94.61 | 333.80 | 480.71 |
| 9. M(Gi)-G-P | 62.34 | 148.62 | 467.28 | 751.61 | 65.34 | 150.73 | 479.91 | 769.43 | 66.27 | 161.18 | 483.91 | 781.06 |
| 10. E(Ci)-M-G | 34.67 | 89.86 | 305.67 | 475.61 | 34.09 | 92.17 | 321.96 | 499.40 | 38.10 | 92.81 | 362.60 | 497.90 |
| SEm (±) | 0.58 | 0.90 | 0.98 | 1.79 | 0.63 | 1.10 | 2.10 | 3.42 | 0.52 | 0.83 | 3.10 | 3.34 |
| CD at 5% | 2.00 | 3.11 | 3.39 | 6.02 | 2.18 | 3.80 | 7.26 | 11.83 | 1.79 | 2.87 | 10.72 | 11.56 |

# TABLE 4.15

## DM accumulation of jute with different systems of cropping

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | | 1999-2000 | | | | | 2000-2001 | | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| 4. Jo-G-P-S | 70.8 | 142.3 | 281.3 | 478.9 | 667.8 | 81.3 | 159.7 | 303.8 | 521.7 | 693.4 | 90.4 | 172.3 | 300.8 | 529.7 | 709.9 |
| 5. Jo-Ra-Rb | 82.9 | 161.0 | 301.8 | 506.7 | 694.1 | 86.4 | 172.3 | 321.4 | 529.4 | 706.1 | 96.2 | 184.1 | 314.7 | 541.9 | 721.2 |
| 't' value | 19.62$^{NS}$ | 30.33$^{NS}$ | 33.25$^{NS}$ | 41.13$^{NS}$ | 42.66$^{NS}$ | 8.27$^{NS}$ | 20.43$^{NS}$ | 28.55$^{NS}$ | 28.06$^{NS}$ | 101.7$^{NS}$ | 9.4$^{NS}$ | 19.14$^{NS}$ | 22.54$^{NS}$ | 19.79$^{NS}$ | 18.33$^{NS}$ |

# TABLE 4.16

## DM accumulation of mustard with different systems of cropping

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| 3. E-Md-S | 124.10 | 281.65 | 416.12 | 492.19 | 130.18 | 294.87 | 416.12 | 502.10 | 120.37 | 284.56 | 441.70 | 501.27 |
| 7. G-Ra-Md | 114.58 | 282.13 | 427.13 | 478.31 | 120.79 | 275.38 | 419.82 | 513.12 | 110.14 | 275.43 | 430.19 | 486.49 |
| 't' value | 15.4$^{NS}$ | 4.0$^{NS}$ | 17.9$^{NS}$ | 22.5$^{NS}$ | 15.2$^{NS}$ | 31.6$^{NS}$ | 6.00$^{NS}$ | 17.1$^{NS}$ | 23.2$^{NS}$ | 14.8$^{NS}$ | 18.7$^{NS}$ | 29.9$^{NS}$ |

# TABLE 4.17

## DM accumulation of sesame with different systems of cropping

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 45 DAS | 60 DAS | 75 DAS | 45 DAS | 60 DAS | 75 DAS | 45 DAS | 60 DAS | 75 DAS |
| 3. E-Md-S | 110.89 | 206.80 | 398.23 | 120.31 | 230.45 | 409.83 | 102.14 | 213.13 | 421.13 |
| 4. Jo-G-P-S | 131.10 | 217.53 | 402.50 | 110.12 | 210.19 | 415.13 | 123.29 | 241.10 | 432.24 |
| 't' value | 32.79$^{NS}$ | 17.40$^{NS}$ | 6.92$^{NS}$ | 16.53$^{NS}$ | 32.86$^{NS}$ | 8.59$^{NS}$ | 34.30$^{NS}$ | 45.37$^{NS}$ | 10.02$^{NS}$ |

## TABLE 4.18

### DM accumulation of groundnut

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
| 6. E-W-Gn | 80.12 | 170.89 | 290.13 | 435.20 | 88.19 | 196.13 | 331.24 | 452.17 | 93.25 | 200.79 | 322.13 | 473.19 |

## TABLE 4.19

### DM accumulation of wheat

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
| 6. E-W-Gn | 88.13 | 123.17 | 449.90 | 689.11 | 92.37 | 131.42 | 463.18 | 711.71 | 83.74 | 132.19 | 466.91 | 732.41 |

## TABLE 4.20

### DM accumulation of elephant-foot yam with different systems of cropping

| Cropping sequence | DM yield (g m$^{-2}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS |
| 2. E-M-G | 367.2 | 596.7 | 901.4 | 1310.5 | 440.3 | 746.3 | 1209.5 | 1712.1 | 453.1 | 762.3 | 1247.4 | 1821.9 |
| 3. E-Md-S | 341.5 | 589.7 | 883.1 | 1300.2 | 468.6 | 769.4 | 1231.7 | 1746.3 | 482.7 | 790.7 | 1289.6 | 1853.1 |
| 6. E-W-Gn | 381.4 | 614.3 | 932.8 | 1368.5 | 428.9 | 723.6 | 1174.8 | 1701.3 | 432.7 | 741.2 | 1219.3 | 1800.3 |
| 10. E(Ci)-M-G | 358.4 | 582.4 | 592.5 | 1302.4 | 431.7 | 736.9 | 1193.3 | 1198.2 | 427.4 | 764.5 | 1241.3 | 1809.1 |
| SEm (±) | 4.35 | 2.42 | 4.20 | 5.64 | 3.94 | 4.24 | 5.74 | 5.24 | 3.40 | 4.80 | 5.94 | 6.10 |
| CD at 5% | 15.05 | 8.37 | 14.50 | 19.51 | 13.63 | 14.67 | 19.86 | 18.13 | 11.76 | 16.61 | 20.55 | 21.10 |

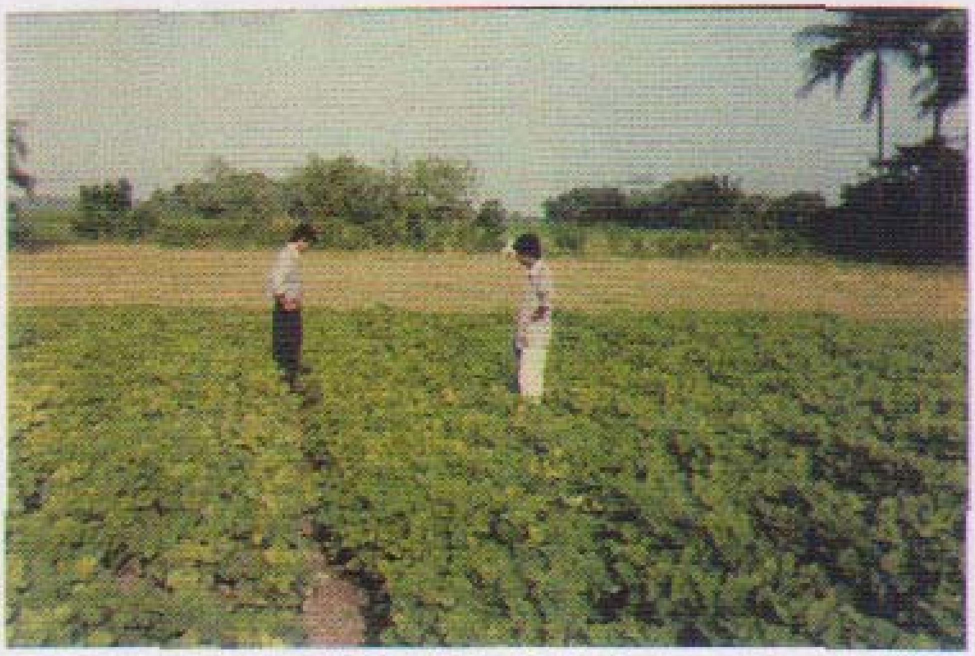


Plate 3 : Greengram in sequence 2 (2000-2001)

Plate 4 : Winter rice at 15 DAT in sequence 8

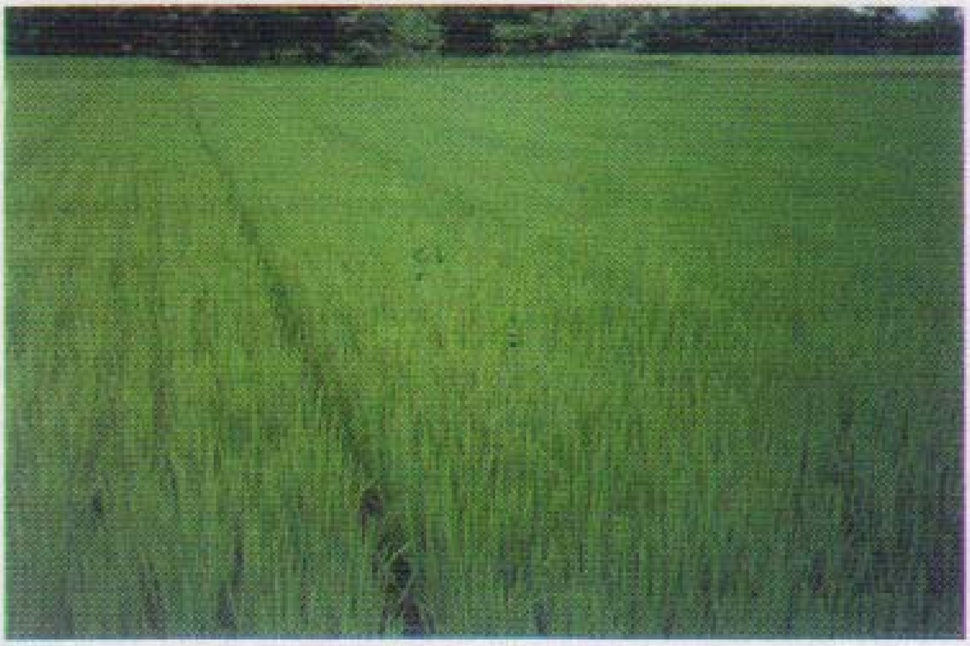


**Plate 5 : Summer rice at 60 DAT in sequence 8 (1999-2000)**

**Plate 6 : Winter rice in sequence 5 after transplanting**

values but afterwards, it increased compared with the same crop raised in other sequences during first two years of investigation. Growing potato in various systems of cropping resulted significant variation in CGR at all the stages (Table 4.22). Higher DM production by potato grown after greengram (sequence 1) resulted in higher CGR in 1$^{st}$ year while the effect of preceding greengram in sequence 4 on CGR of potato seemed more pronounced in latter two years.Beneficial effect of preceding jute and greengram in succession in increasing the availability of soil nutrients to succeeding potato became more pronounced. Bhunia *et al.* (1997a) earlier made similar observation.

### 4.1.3.3 CGR of rice

Significant variation was noted in CGR values of rice grown in different cropping sequences at all the stages of crop growth (Table 4.23). The winter rice showed increase in CGR upto 60 DAT which declined thereafter; in case of summer rice, CGR was found to decrease slightly during 45 – 60 DAT compared with the initial one which again increased during 60 – 75 DAT. Both the rices, grown in different sequences, showed no variation among themselves at any stage of growth. Summer rice showed higher CGR values as compared to winter one at all the stages except during 45 – 60 DAT in 1$^{st}$ year.

### 4.1.3.4 CGR of maize

Maize recorded the highest CGR value during 45 – 60 DAS, later on decreased during 60 – 75 DAS (Table 4.24). Growing maize in different systems of cropping resulted significant variation in CGR at all the stages of growth. Higher growth and DM production in summer maize resulted in higher CGR value at all the stages than maize grown during winter. The highest CGR values were noted during 45 – 60 DAS during all the three years of investigation. Higher CGR in sequences 1 and 9, wherein it was grown after potato, might be due to the influence of preceding potato crop by way of increasing residual fertility of soil.

### 4.1.3.5 CGR of jute

Growing jute in two cropping sequences showed little variation in CGR at all the stages during all the three years of cropping. It showed gradual increase in CGR upto 75 DAS and then declined slightly during 75-90 DAS (Table 4.25). Jute grown in sequence 5 showed slightly higher CGR values than in sequence 4 at most of the stages of growth.

#### 4.1.3.6 CGR of mustard

Mustard recorded very high CGR values (upto 60 DAS) which thereafter gradually declined with the progress of growth. Mustard in different systems of cropping showed no significant variation in CGR at any stage of growth (Table 4.26). Influence of preceding crops of elephant-foot yam and winter rice in sequence 3 and 7 on growth, DM production and CGR of mustard grown thereafter did not reflect any definite trend of superiority to one over the other.

#### 4.1.3.7 CGR of sesame

Sesame showed low CGR during early growth stage (45 – 60 DAS) which increased to double or even more during 60 –75 DAS (Table 4.27). CGR during 45 – 60 DAS was slightly lower in 1$^{st}$ year which latter on improved. Growing sesame in different cropping sequences showed no superiority to one another in respect of CGR.

#### 4.1.3.8 CGR of groundnut

CGR of groundnut exhibited gradual increase from 30 to 75 DAS in 1$^{st}$ and 3$^{rd}$ year; while during 2$^{nd}$ year, it decreased slightly during 60 – 75 DAS. The highest value of CGR (10.07 g $m^{-2}$ $d^{-1}$) was noted during 60 – 75 DAS in 3$^{rd}$ year (Table 4.28).

#### 4.1.3.9 CGR of wheat

Wheat showed very low CGR at the beginning which reached the peak during 45-60 DAS and declined thereafter (Table 4.29). The highest value of 22.30 g $m^{-2}$ $d^{-1}$ was noted during 45-60 DAS in 3$^{rd}$ year.

#### 4.1.3.10 CGR of elephant-foot yam

CGR of elephant-foot yam showed gradual increase in values with the progress of crop growth (Table 4.30). Elephant-foot yam recorded significant variation in CGR at all stages during all the three years of experimentation except during 60 –90 DAS in 2nd year. Elephant-foot yam grown in sequence 6 after groundnut, recorded the highest CGR value during 120 – 150 DAS in all the years Beneficial effect of preceding legume crop of groundnut towards DM production and CGR of succeeding elephant-foot yam seemed evident by way of producing the highest CGR values during all the years. Similar beneficial effect of a legume on the following crop in rotation was earlier reported by Ahlawat *et al.* (1981).

### 4.1.4 Root studies

#### 4.1.4.1 Volume of root

##### 4.1.4.1.1 Volume of root of greengram

No variation was noticed with regard to volume of root plant$^{-1}$ (cc) of greengram due to the practice of different systems of cropping during the three years period of experimentation (Table 4.31). With the advancement of growth, volume of root was found to increase recording the maximum volume at 60 DAS irrespective of the practice of cropping sequences. However, greengram, after maize in sequence 10, recorded the greatest volume of root (1.78 cc plant$^{-1}$) in 2nd and 3rd year of cropping; while greengram after jute (sequence 4) recorded the maximum root volume in 1st year of cropping. Root volume was slightly lower in intercropped greengram (sequence 9) due to the competition between the component crops. There was little impact of preceding crop on root volume although the crop recorded slightly higher volume of root when succeeded jute.

##### 4.1.4.1.2 Volume of root of rice

With the advancement of crop growth, volume of rice root was increased upto 75 DAT and there was variation due to the practice of different systems of cropping. Little variation was noticed regarding the volume of rice roots grown during the wet as well as dry (*boro*) season. Root volume of summer rice was higher in all the 3 years of cropping irrespective of the cropping sequences tried which was due to the better utilization of growth resources. The highest volume of root of winter rice was obtained at 75 DAT in sequence 8, *i.e.*, Gm-Ra-Rb. This sequence recorded higher root volume at all the stages of growth. In summer rice, the highest root volume was noted at 75 DAT in sequence 8 during all the three years (Table 4.32).

## TABLE 4.21

### CGR of greengram with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | | 1999-2000 | | 2000-2001 | |
| | 30-45 DAS | 45-60 DAS | 30-45 DAS | 45-60 DAS | 30-45 DAS | 45-60 DAS |
| 1. M-G-P | 12.82 | 3.74 | 12.84 | 3.01 | 13.51 | 2.50 |
| 2. E-M-G | 12.18 | 2.80 | 13.42 | 2.85 | 14.22 | 3.57 |
| 4. Jo-G-P-S | 12.94 | 4.48 | 13.91 | 4.33 | 14.33 | 4.06 |
| 7. G-Ra-Md | 12.78 | 3.31 | 13.38 | 3.61 | 13.48 | 3.26 |
| 9. M(Gi)-G-P | *(5.93) | (3.10) | (6.05) | (3.87) | (6.61) | (2.75) |
| | 12.72 | 3.45 | 12.80 | 3.21 | 11.20 | 3.91 |
| 10. E(Ci)-M-G | 11.92 | 2.11 | 13.40 | 3.67 | 13.73 | 3.79 |
| SEm (±) | 0.54 | 0.44 | 0.43 | 0.48 | 0.50 | 0.41 |
| CD at 5% | 1.66 | 1.35 | 1.32 | 1.47 | 1.54 | 1.26 |

* Intercrop value

## TABLE 4.22

### CGR of potato with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 40-60 DAS | 60-80 DAS | 80-100 DAS | 40-60 DAS | 60-80 DAS | 80-100 DAS | 40-60 DAS | 60-80 DAS | 80-100 DAS |
| 1. M-G-P | 5.64 | 12.15 | 5.93 | 4.76 | 12.18 | 4.60 | 4.74 | 13.57 | 4.12 |
| 4. Jo-G-P-S | 5.15 | 11.75 | 4.93 | 5.47 | 11.57 | 4.51 | 5.90 | 11.12 | 5.81 |
| 9. M(Gi)-G-P | 4.42 | 12.33 | 7.60 | 4.70 | 13.57 | 5.34 | 5.52 | 12.13 | 5.50 |
| SEm (±) | 0.02 | 0.04 | 0.06 | 0.03 | 0.04 | 0.05 | 0.04 | 0.03 | 0.02 |
| CD at 5% | 0.07 | 0.15 | 0.23 | 0.12 | 0.15 | 0.19 | 0.15 | 0.12 | 0.07 |

## TABLE 4.23

## CGR of rice with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 30-45 DAT | 45-60 DAT | 60-75 DAT | 30-45 DAT | 45-60 DAT | 60-75 DAT | 30-45 DAT | 45-60 DAT | 60-75 DAT |
| ✪ *Aman* | | | | | | | | | |
| 5. Jo-Ra-Rb | 10.00 | 14.46 | 7.33 | 10.24 | 11.86 | 8.72 | 7.42 | 12.44 | 8.82 |
| 7. G-Ra-Md | 10.04 | 13.42 | 9.91 | 10.00 | 12.56 | 8.10 | 8.75 | 13.90 | 9.79 |
| 8. Gm-Ra-Rb | 10.02 | 12.34 | 9.93 | 11.02 | 12.11 | 10.58 | 8.89 | 11.93 | 9.34 |
| ✪ *Boro* | | | | | | | | | |
| 5. Jo-Ra-Rb | 12.76 | 8.81 | 12.44 | 11.21 | 10.14 | 11.24 | 12.10 | 10.80 | 11.93 |
| 8. Gm-Ra-Rb | 12.71 | 10.08 | 11.90 | 12.12 | 10.51 | 10.24 | 11.76 | 10.57 | 12.50 |
| SEm (±) | 0.43 | 0.57 | 0.60 | 0.40 | 0.43 | 0.54 | 0.43 | 0.48 | 0.60 |
| CD at 5% | 1.40 | 1.85 | 1.95 | 1.30 | 1.40 | 1.76 | 1.40 | 1.56 | 1.95 |

## TABLE 4.24

## CGR of maize with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 30-45 DAS | 45-60 DAS | 60-75 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS |
| 1. M-G-P | 5.36 | 21.33 | 18.20 | 5.39 | 21.30 | 20.84 | 5.87 | 20.63 | 20.56 |
| 2. E-M-G | 3.58 | 14.88 | 10.66 | 3.44 | 14.82 | 11.62 | 3.70 | 15.94 | 9.79 |
| 9. M(Gi)-G-P | 5.75 | 21.22 | 18.93 | 5.69 | 21.94 | 19.30 | 6.32 | 21.50 | 19.81 |
| 10. E(Ci)-M-G | 3.67 | 14.38 | 11.32 | 3.87 | 15.31 | 11.82 | 3.64 | 17.98 | 9.02 |
| SEm (±) | 0.03 | 0.20 | 0.28 | 0.19 | 0.22 | 0.04 | 0.05 | 0.35 | 0.05 |
| CD at 5% | 0.11 | 0.69 | 0.96 | 0.65 | 0.76 | 0.13 | 0.16 | 1.21 | 0.17 |

# TABLE 4.25

## CGR of jute with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | | 1999-2000 | | | | 2000-2001 | | | |
| | 30-45 DAS | 45-60 DAS | 60-75 DAS | 75-90 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS | 75-90 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS | 75-90 DAS |
| 4. Jo-G-P-S | 4.70 | 9.26 | 13.17 | 12.51 | 5.22 | 9.60 | 14.52 | 11.44 | 5.46 | 8.56 | 15.26 | 12.01 |
| 5. Jo-Ra-Rb | 5.20 | 9.38 | 13.67 | 12.49 | 5.72 | 9.94 | 13.86 | 11.78 | 5.86 | 8.70 | 15.14 | 11.95 |
| 't' value | $9.67^{NS}$ | $2.63^{NS}$ | $4.75^{NS}$ | $0.43^{NS}$ | $10.9^{NS}$ | $7.49^{NS}$ | $14.51^{NS}$ | $7.19^{NS}$ | $8.79^{NS}$ | $3.07^{NS}$ | $2.69^{NS}$ | $4.31^{NS}$ |

# TABLE 4.26

## CGR of mustard with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 45-60 DAS | 60-75 DAS | 75-90 DAS | 45-60 DAS | 60-75 DAS | 75-90 DAS | 45-60 DAS | 60-75 DAS | 75-90 DAS |
| 3. E-Md-S | 10.50 | 8.96 | 5.07 | 10.97 | 8.08 | 5.73 | 10.94 | 10.47 | 3.97 |
| 7. G-Ra-Md | 11.17 | 9.66 | 3.40 | 10.30 | 9.62 | 6.22 | 11.00 | 10.28 | 3.72 |
| 't' value | $1.47^{NS}$ | $1.53^{NS}$ | $3.67^{NS}$ | $1.47^{NS}$ | $3.38^{NS}$ | $1.07^{NS}$ | $2.99^{NS}$ | $0.41^{NS}$ | $0.54^{NS}$ |

# TABLE 4.27

## CGR of sesame with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | | 1999-2000 | | 2000-2001 | |
| | 45-60 DAS | 60-75 DAS | 45-60 DAS | 60-75 DAS | 45-60 DAS | 60-75 DAS |
| 3. E-Md-S | 6.39 | 12.76 | 7.34 | 11.95 | 7.39 | 13.86 |
| 4. Jo-G-P-S | 5.76 | 12.33 | 6.67 | 13.66 | 7.85 | 12.74 |
| 't' value | $13.85^{NS}$ | $9.45^{NS}$ | $14.73^{NS}$ | $36.95^{NS}$ | $10.11^{NS}$ | $12.43^{NS}$ |

## TABLE 4.28

## CGR of groundnut

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 30-45 DAS | 45-60 DAS | 60-75 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS |
| 6. E-W-Gn | 6.05 | 7.94 | 9.67 | 7.00 | 9.92 | 8.06 | 7.83 | 8.09 | 10.07 |

## TABLE 4.29

## CGR of wheat

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 30-45 DAS | 45-60 DAS | 60-75 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS | 30-45 DAS | 45-60 DAS | 60-75 DAS |
| 6. E-W-Gn | 2.33 | 21.78 | 15.94 | 2.60 | 22.10 | 16.56 | 3.23 | 22.30 | 17.70 |

## TABLE 4.30

## CGR of elephant-foot yam with different systems of cropping

| Cropping sequence | CGR ($g\ m^{-2}\ d^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | | | 1999-2000 | | | 2000-2001 | | |
| | 60-90 DAS | 90-120 DAS | 120-150 DAS | 60-90 DAS | 90-120 DAS | 120-150 DAS | 60-90 DAS | 90-120 DAS | 120-150 DAS |
| 2. E-M-G | 7.75 | 10.15 | 13.63 | 10.20 | 15.44 | 16.75 | 10.30 | 16.17 | 19.15 |
| 3. E-Md-S | 8.27 | 9.78 | 13.90 | 10.01 | 15.41 | 17.15 | 10.26 | 16.63 | 18.78 |
| 6. E-W-Gn | 7.76 | 10.61 | 14.52 | 9.82 | 15.04 | 17.55 | 10.28 | 15.93 | 19.36 |
| 10. E(Ci)-M-G | 7.46 | 10.34 | 13.61 | 10.16 | 15.20 | 16.84 | 11.23 | 15.89 | 18.91 |
| SEm (±) | 0.35 | 0.21 | 0.30 | 0.41 | 0.10 | 0.25 | 0.21 | 0.19 | 0.15 |
| CD at 5% | 1.21 | 0.72 | 1.03 | NS | 0.34 | 0.86 | 0.72 | 0.65 | 0.51 |

Plate 7 : Jute at 70 DAS in sequence 4 ( 1999-2000)

Plate 8 : Jute at 70 DAS in sequence 5 ( 1999-2000)

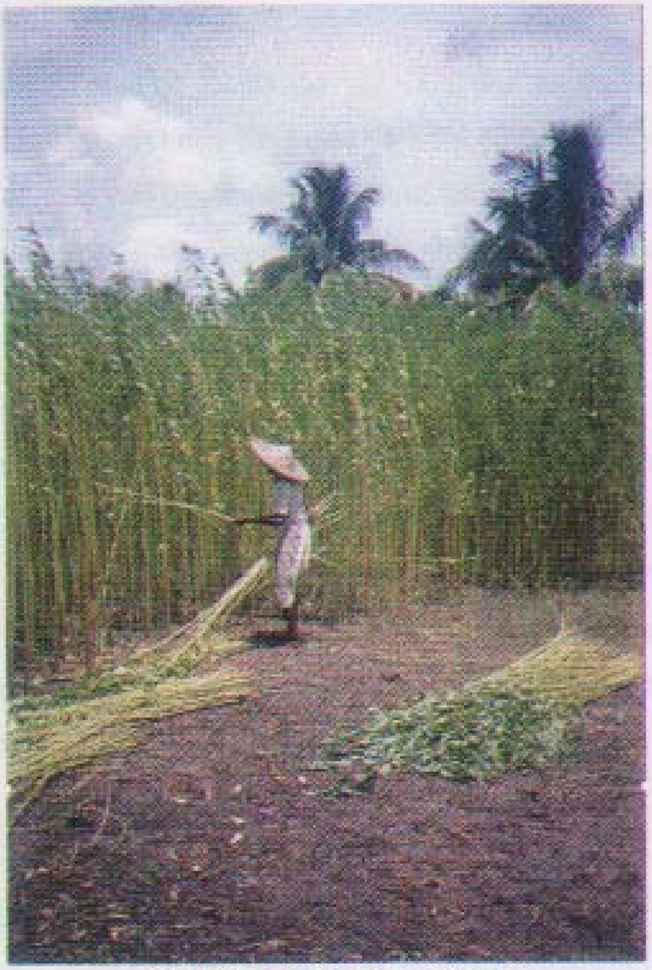


Plate 9 : Harvesting of jute

Plate 10 : Jute after harvesting (1999-2000)

#### 4.1.4.1.3 Volume of root of maize

The volume of root of maize did not vary due to the adoption of various systems of cropping. Root volume increased with the advancement of growth and the greatest volume of root was obtained at 80 DAS in sequence 1 (M-G-P) in all the three years of cropping while maize grown after elephant-foot yam gave rise comparatively to lower volume of root (Table 4.33).

#### 4.1.4.1.4 Volume of root of jute

Jute showed progressive increase in root volume with the advancement of growth upto 75 DAS and thereafter it declined slightly at 90 DAS (Table 4.34). The greatest increase was seen between 45 and 60 DAS. The highest root volume was recorded at 75 DAS in sequence 5 in all the three years of cropping. Jute, raised after summer rice (sequence 5), showed slightly higher root volume than jute grown after sesame (sequence 4).

#### 4.1.4.1.5 Volume of root of mustard

Little variation was noticed towards the volume of root of mustard in various systems of cropping during all the three years of experimentation (Table 4.35). The greatest volume of root was found at 80 DAS (5.19 cc $plant^{-1}$) in sequence 7 during 1$^{st}$ year. In general, root volume was increased upto 80 DAS.

#### 4.1.4.1.6 Volume of root of sesame

With the advancement of growth, root volume of sesame in different systems of cropping increased although there was little variation (Table 4.36). Sesame, grown after potato in sequence 4, recorded slightly higher root volume at all the growth stages compared with sesame grown after mustard in sequence 3. The maximum volume of root (6.73 cc $plant^{-1}$) was found in sequence 4 at 80 DAS in 3$^{rd}$ year.

#### 4.1.4.1.7 Volume of root of groundnut

Groundnut showed progressive increase in root volume reaching the highest value at 80 DAS. The maximum volume of root (3.04 cc $plant^{-1}$) was noted at 80 DAS in 3$^{rd}$ year (Table 4.37).

#### 4.1.4.1.8 Volume of root of wheat

With the advancement of growth, root volume went on increasing attaining the highest value at 80 DAS. The maximum root volume was noted at 80 DAS in 3rd year. Very little variation was seen towards the root volume of wheat at different growth stages during all the three years of experimentation (Table 4.38).

### 4.1.4.2 Dry weight of root

#### 4.1.4.2.1 Dry weight of root of greengram

The dry weight of root plant$^{-1}$ (g) increased with the advancement of growth of greengram plant but no significant variation towards dry weight of root due to the practice of different systems of cropping in any of the three years of crop growth was noticed. The highest root dry weight (0.818 g plant$^{-1}$) was noticed in sequence 10 during both 2nd and 3rd year of cropping at 60 DAS. Root dry weight was comparatively lower when greengram was grown after maize as in sequences 1 and 2, while greengram grown after jute or mustard showed slightly higher root dry weight. At 60 DAS, the lowest root dry weight was noticed in sequence 2 (0.754 g plant$^{-1}$) in 1st year (Table 4.39).

#### 4.1.4.2.2 Dry weight of root of rice

The dry weight of root plant$^{-1}$ was influenced significantly due to the different systems of cropping at 45, 60 and at 75 DAT (Table 4.40). However, little variation was noticed between the rices grown during wet and dry seasons. Winter rice recorded the highest root dry weight (1.18 g plant$^{-1}$) at 75 DAT in 2nd year. Root dry weight showed progressive increase upto 75 DAT with the highest increment took place between 30 and 45 DAT. Summer rice recorded the highest root dry weight (1.26 g plant$^{-1}$) at 75 DAT in sequence 5 during 2nd year.

#### 4.1.4.2.3 Dry weight of root of maize

No significant variation towards the dry weight of root of maize was noticed in different systems of cropping (Table 4.41). Root dry weight showed progressive increase with the advancement of growth. The highest root dry weight (10.04 g plant$^{-1}$) was obtained at 80 DAS from sequence 1 during 3rd year while sequence 2

# TABLE 4.31

## Volume of root of greengram with different systems of cropping

| Cropping sequence | Root volume plant$^{-1}$ (cc) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 0.38 | 0.36 | 0.39 | 1.37 | 1.39 | 1.40 | 1.60 | 1.57 | 1.61 |
| 2. E-M-G | 0.37 | 0.39 | 0.38 | 1.35 | 1.40 | 1.42 | 1.53 | 1.60 | 1.59 |
| 4. Jo-G-P-S | 0.42 | 0.43 | 0.45 | 1.41 | 1.43 | 1.43 | 1.72 | 1.70 | 1.71 |
| 7. G-Ra-Md | 0.39 | 0.40 | 0.43 | 1.30 | 1.34 | 1.41 | 1.70 | 1.72 | 1.74 |
| 9. M(Gi)-G-P | *(0.34) | (0.35) | (0.41) | (1.32) | (1.41) | (1.39) | (1.65) | (1.68) | (1.69) |
| | 0.44 | 0.48 | 0.42 | 1.40 | 1.42 | 1.44 | 1.74 | 1.74 | 1.76 |
| 10. E(Ci)-M-G | 0.32 | 0.36 | 0.40 | 1.38 | 1.46 | 1.48 | 1.71 | 1.78 | 1.78 |
| SEm (±) | 0.049 | 0.052 | 0.046 | 0.12 | 0.17 | 0.21 | 0.11 | 0.24 | 0.26 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS | NS | NS |

* Intercrop value

# TABLE 4.32

## Volume of root of rice with different systems of cropping

| Cropping sequence | Root volume m$^{-2}$ (cc) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAT | | | 45 DAT | | | 60 DAT | | | 75 DAT | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| ✪ *Aman* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 11.4 | 12.0 | 12.9 | 50.4 | 51.1 | 52.4 | 83.1 | 82.7 | 83.2 | 93.6 | 94.8 | 94.1 |
| 7. G-Ra-Md | 12.1 | 12.9 | 13.4 | 52.1 | 53.0 | 53.2 | 86.0 | 85.4 | 86.2 | 94.8 | 96.0 | 96.8 |
| 8. Gm-Ra-Rb | 13.2 | 14.2 | 15.6 | 51.2 | 52.2 | 53.0 | 87.6 | 86.3 | 87.8 | 96.9 | 99.1 | 99.8 |
| ✪ *Boro* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 15.5 | 16.1 | 17.4 | 55.1 | 61.3 | 62.2 | 95.1 | 97.2 | 96.5 | 105.1 | 106.6 | 108.4 |
| 8. Gm-Ra-Rb | 17.3 | 17.9 | 19.1 | 59.4 | 63.2 | 64.1 | 96.8 | 98.3 | 99.2 | 107.2 | 107.5 | 109.9 |
| SEm(±) | 0.54 | 0.45 | 0.64 | 0.86 | 0.91 | 0.98 | 1.25 | 1.10 | 1.20 | 1.54 | 1.62 | 1.39 |
| CD at 5% | 1.76 | 1.46 | 2.08 | 2.80 | 2.96 | 3.19 | 4.07 | 3.58 | 3.91 | 5.02 | 5.28 | 4.53 |

## TABLE 4.33

### Volume of root of maize with different systems of cropping

| Cropping sequence | Root volume plant$^{-1}$ (cc) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 8.03 | 11.13 | 10.87 | 17.12 | 18.10 | 18.86 | 24.04 | 26.94 | 24.13 |
| 2. E-M-G | 6.12 | 7.90 | 8.13 | 12.14 | 12.93 | 15.45 | 20.07 | 23.10 | 22.07 |
| 9. M(Gi)-G-P | 7.03 | 10.13 | 10.90 | 16.30 | 16.61 | 17.46 | 20.49 | 24.23 | 21.19 |
| 10. E(Ci)-M-G | 6.29 | 7.84 | 8.00 | 13.12 | 13.15 | 13.09 | 22.14 | 21.76 | 22.28 |
| SEm (±) | 0.92 | 0.98 | 0.86 | 1.52 | 1.60 | 1.69 | 1.24 | 1.74 | 0.98 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## TABLE 4.34

### Volume of root of jute with different systems of cropping

| Cropping sequence | Root volume plant$^{-1}$ (cc) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | | 75 DAS | | | 90 DAS | | |
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 4. Jo-G-P-S | 0.42 | 0.43 | 0.41 | 1.41 | 1.38 | 1.51 | 3.80 | 3.84 | 3.96 | 4.72 | 4.90 | 5.10 | 4.21 | 4.28 | 4.30 |
| 5. Jo-Ra-Rb | 0.46 | 0.45 | 0.46 | 1.43 | 1.43 | 1.60 | 3.93 | 3.93 | 3.84 | 4.81 | 4.94 | 5.25 | 4.31 | 4.31 | 4.46 |
| 't' value | 0.51$^{NS}$ | 0.74$^{NS}$ | 0.39$^{NS}$ | 1.10$^{NS}$ | 2.12$^{NS}$ | 2.41$^{NS}$ | 1.79$^{NS}$ | 2.17$^{NS}$ | 1.45$^{NS}$ | 2.10$^{NS}$ | 3.26$^{NS}$ | 2.50$^{NS}$ | 3.14$^{NS}$ | 2.62$^{NS}$ | 1.48$^{NS}$ |

## TABLE 4.35

### Volume of root of mustard with different systems of cropping

| Cropping sequence | Root volume plant$^{-1}$ (cc) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 2.20 | 1.90 | 2.28 | 4.06 | 4.13 | 4.10 | 5.02 | 5.12 | 5.17 |
| 7. G-Ra-Md | 2.06 | 2.10 | 2.20 | 4.12 | 4.00 | 4.06 | 5.19 | 5.07 | 5.09 |
| 't' value | 2.52$^{NS}$ | 1.86$^{NS}$ | 2.40$^{NS}$ | 3.74$^{NS}$ | 2.99$^{NS}$ | 3.21$^{NS}$ | 4.10$^{NS}$ | 3.98$^{NS}$ | 4.26$^{NS}$ |

## TABLE 4.36

### Volume of root of sesame with different systems of cropping

| Cropping sequence | Root volume plant$^{-1}$ (cc) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 2.48 | 2.60 | 2.77 | 4.35 | 4.62 | 4.30 | 6.03 | 6.25 | 6.40 |
| 4. Jo-G-P-S | 2.79 | 2.92 | 2.95 | 4.82 | 4.83 | 5.00 | 6.24 | 6.49 | 6.73 |
| 't' value | 2.16$^{NS}$ | 1.80$^{NS}$ | 1.99$^{NS}$ | 2.64$^{NS}$ | 3.42$^{NS}$ | 1.89$^{NS}$ | 2.64$^{NS}$ | 3.47$^{NS}$ | 2.90$^{NS}$ |

## TABLE 4.37

### Volume of root of groundnut

| Cropping sequence | Root volume plant$^{-1}$ (cc) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 1.43 | 1.50 | 1.49 | 1.81 | 1.93 | 2.05 | 2.78 | 2.90 | 3.04 |

## TABLE 4.38

### Volume of root of wheat

| Cropping sequence | Root volume plant$^{-1}$ (cc) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 0.54 | 0.61 | 0.64 | 1.20 | 1.29 | 1.36 | 2.10 | 2.26 | 2.34 |

showed the lowest root dry weight (7.04 g plant$^{-1}$) at the same date on 2$^{nd}$ year. Maize grown after potato (sequences 1 and 9) showed slightly higher root dry weight than grown after elephant-foot yam at 60 and at 80 DAS.

**4.1.4.2.4 Dry weight of root of jute**

Root dry weight of jute varied slightly in different systems of cropping over the years (Table 4.42). It showed gradual increase in root dry weight upto 75 DAS and thereafter it slightly declined. The highest root dry weight (3.61 g plant$^{-1}$) was obtained at 75 DAS in sequence 5 during 3$^{rd}$ year.

**4.1.4.2.5 Dry weight of root of mustard**

The dry weight of mustard root showed slight variation in different systems of cropping during all the three years of study (Table 4.43). Root dry weight was higher in sequence 7 at almost all the growth stages when mustard was grown after winter rice in all the three years. The highest root dry weight was obtained at 80 DAS with sequence 7 in 1$^{st}$ year.

**4.1.4.2.6 Dry weight of root of sesame**

Though there was very little variation towards the dry weight of root of sesame raised in different systems of cropping, nevertheless, sesame grown after potato (sequence 4) showed slightly higher values in all the three years of cropping (Table 4.44). The dry weight of root recorded progressive increase with the highest value (2.64 g plant$^{-1}$) found in sequence 4 at 80 DAS in 2$^{nd}$ year.

**4.1.4.2.7 Dry weight of root of groundnut**

The root dry weight of groundnut showed progressive increase in values with the highest being at 80 DAS. The variation in root dry weight at different growth stages was less pronounced in all the three years of cropping. The highest value (2.70 g plant$^{-1}$) was noted in 3$^{rd}$ year at 80 DAS (Table 4.45)

**4.1.4.2.8 Dry weight of root of wheat**

Wheat showed gradual increase in root dry weight as the growth progressed. The highest root dry weight (0.68 g plant$^{-1}$) was noticed in the 3$^{rd}$ year of cropping at 80 DAS (Table 4.46).

### 4.1.5 Nodulation studies

#### 4.1.5.1 Number of effective nodules

##### 4.1.5.1.1 Number of effective nodules of greengram

Number of effective nodules plant$^{-1}$ was increased upto 45 DAS in greengram with all the cropping sequences and thereafter, the number decreased during 60 DAS (Table 4.47). The highest number of effective nodule (35.2 plant$^{-1}$) at 45 DAS was observed in sequence 4 during the entire 3 years period where greengram was grown after jute. Number of effective nodules was lower when greengram was grown as intercrop with maize (sequence 9) which might be attributed to the effect of shading by the tall growing maize component and top dressing of higher dose of nitrogen in maize rows. No adverse phytotoxic effect of arsenic was noted on nodule growth and number.

##### 4.1.5.1.2 Number of effective nodules of groundnut

In groundnut, nodule number plant$^{-1}$ showed an increasing trend upto 75 DAS as the growth progressed and thereafter, it declined due to senescence. The highest number of effective nodule plant$^{-1}$ (262.4) was noted at 75 DAS in 3$^{rd}$ year (Table 4.48).

##### 4.1.5.1.3 Number of effective nodules of green manure

Number of effective nodules plant$^{-1}$ in green manure was lower than usual which might be due to poor stand establishment and poor management. It recorded the highest number of nodule (24.0 plant$^{-1}$) at harvest in 2$^{nd}$ year (Table 4.49).

#### 4.1.5.2 Dry weight of nodules

##### 4.1.5.2.1 Dry weight of nodules of greengram

Dry weight of nodules plant$^{-1}$ of greengram increased upto 60 DAS (Table 4.50). Very little variation in dry weight of nodules plant$^{-1}$ of greengram was noted due to the various cropping sequences. The highest amount of dry weight of nodules plant$^{-1}$ (0.127 g) was noted at 60 DAS from cropping sequence 4 in 3$^{rd}$ year. The dry weight was lower in intercropped greengram (sequence 9) which might be due to lower number of nodules plant$^{-1}$ in intercrop. So far, no phytotoxic or adverse effect of arsenic was noted towards the dry weight of nodules.

## TABLE 4.39

### Dry weight of root of greengram with different systems of cropping

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 0.129 | 0.138 | 0.161 | 0.310 | 0.350 | 0.354 | 0.767 | 0.787 | 0.783 |
| 2. E-M-G | 0.114 | 0.149 | 0.171 | 0.301 | 0.352 | 0.364 | 0.754 | 0.783 | 0.765 |
| 4. Jo-G-P-S | 0.147 | 0.167 | 0.173 | 0.316 | 0.364 | 0.371 | 0.804 | 0.843 | 0.815 |
| 7. G-Ra-Md | 0.138 | 0.152 | 0.160 | 0.309 | 0.347 | 0.360 | 0.800 | 0.764 | 0.802 |
| 9. M(Gi)-G-P | *(0.134) | (0.140) | (0.153) | (0.300) | (0.343) | (0.359) | (0.780) | (0.840) | (0.800) |
| | 0.141 | 0.156 | 0.168 | 0.303 | 0.359 | 0.369 | 0.817 | 0.796 | 0.809 |
| 10. E(Ci)-M-G | 0.132 | 0.142 | 0.157 | 0.304 | 0.361 | 0.343 | 0.791 | 0.818 | 0.818 |
| SEm (±) | 0.15 | 0.14 | 0.11 | 0.06 | 0.05 | 0.08 | 0.05 | 0.07 | 0.05 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS | NS | NS |

* Intercrop value

## TABLE 4.40

### Dry weight of root of rice with different systems of cropping

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAT | | | 45 DAT | | | 60 DAT | | | 75 DAT | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| ○ *Aman* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 0.16 | 0.24 | 0.27 | 0.60 | 0.65 | 0.67 | 0.83 | 0.85 | 0.92 | 0.98 | 1.06 | 1.10 |
| 7. G-Ra-Md | 0.18 | 0.25 | 0.24 | 0.58 | 0.67 | 0.69 | 0.85 | 0.88 | 1.04 | 1.05 | 1.10 | 1.09 |
| 8. Gm-Ra-Rb | 0.21 | 0.27 | 0.29 | 0.62 | 0.69 | 0.71 | 0.88 | 0.92 | 1.09 | 1.10 | 1.18 | 1.16 |
| ○ *Boro* | | | | | | | | | | | | |
| 5. Jo-Ra-Rb | 0.20 | 0.29 | 0.31 | 0.74 | 0.76 | 0.77 | 1.05 | 1.08 | 1.04 | 1.21 | 1.26 | 1.25 |
| 8. Gm-Ra-Rb | 0.22 | 0.32 | 0.34 | 0.76 | 0.75 | 0.79 | 1.08 | 1.10 | 1.08 | 1.23 | 1.23 | 1.22 |
| SEm(±) | 0.032 | 0.045 | 0.061 | 0.051 | 0.041 | 0.045 | 0.064 | 0.059 | 0.042 | 0.056 | 0.041 | 0.037 |
| CD at 5% | NS | NS | NS | 0.16 | 0.13 | 0.14 | 0.20 | 0.19 | 0.13 | 0.18 | 0.13 | 0.12 |

## TABLE 4.41

### Dry weight of root of maize with different systems of cropping

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 2.69 | 3.14 | 3.19 | 7.10 | 8.09 | 9.04 | 8.79 | 9.12 | 10.04 |
| 2. E-M-G | 2.49 | 2.70 | 2.75 | 4.03 | 6.02 | 7.98 | 7.07 | 7.04 | 9.02 |
| 9. M(Gi)-G-P | 2.14 | 3.00 | 3.22 | 6.74 | 7.34 | 8.38 | 7.30 | 8.64 | 9.00 |
| 10. E(Ci)-M-G | 2.58 | 2.82 | 2.94 | 4.23 | 6.24 | 8.19 | 7.25 | 7.32 | 9.43 |
| SEm (±) | 0.39 | 0.51 | 0.47 | 0.68 | 0.74 | 0.61 | 0.86 | 0.73 | 0.94 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## TABLE 4.42

### Dry weight of root of jute with different systems of cropping

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | | 75 DAS | | | 90 DAS | | |
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 4. Jo-G-P-S | 0.29 | 0.30 | 0.31 | 1.41 | 1.48 | 1.54 | 2.68 | 2.50 | 2.72 | 3.39 | 3.41 | 3.51 | 3.21 | 3.34 | 3.21 |
| 5. Jo-Ra-Rb | 0.31 | 0.31 | 0.32 | 1.42 | 1.51 | 1.58 | 2.76 | 2.69 | 2.69 | 3.32 | 3.30 | 3.61 | 3.32 | 3.30 | 3.32 |
| 't' value | 0.64$^{NS}$ | 0.47$^{NS}$ | 0.84$^{NS}$ | 1.23$^{NS}$ | 1.45$^{NS}$ | 1.81$^{NS}$ | 1.95$^{NS}$ | 2.22$^{NS}$ | 2.43$^{NS}$ | 2.98$^{NS}$ | 2.62$^{NS}$ | 2.17$^{NS}$ | 2.10$^{NS}$ | 2.64$^{NS}$ | 2.95$^{NS}$ |

## TABLE 4.43

### Dry weight of root of mustard with different systems of cropping

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 0.371 | 0.306 | 0.432 | 0.825 | 0.817 | 0.751 | 0.906 | 0.890 | 0.834 |
| 7. G-Ra-Md | 0.342 | 0.394 | 0.405 | 0.892 | 0.737 | 0.724 | 0.970 | 0.799 | 0.828 |
| 't' value | 0.68$^{NS}$ | 0.95$^{NS}$ | 0.99$^{NS}$ | 1.12$^{NS}$ | 1.34$^{NS}$ | 1.49$^{NS}$ | 2.14$^{NS}$ | 1.47$^{NS}$ | 1.49$^{NS}$ |

## TABLE 4.44

### Dry weight of root of sesame with different systems of cropping

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 1.13 | 1.41 | 1.07 | 1.98 | 2.35 | 1.97 | 2.13 | 2.52 | 2.40 |
| 4. Jo-G-P-S | 1.35 | 1.42 | 1.34 | 2.13 | 2.18 | 2.30 | 2.39 | 2.64 | 2.61 |
| 't' value | 1.49$^{NS}$ | 1.64$^{NS}$ | 1.85$^{NS}$ | 2.46$^{NS}$ | 2.74$^{NS}$ | 3.10$^{NS}$ | 1.46$^{NS}$ | 1.89$^{NS}$ | 2.10$^{NS}$ |

## TABLE 4.45

### Dry weight of root of groundnut

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 1.23 | 1.36 | 1.39 | 2.05 | 2.13 | 2.20 | 2.53 | 2.64 | 2.70 |

## TABLE 4.46

### Dry weight of root of wheat

| Cropping sequence | Root dry weight plant$^{-1}$ (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | | 60 DAS | | | 80 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 0.20 | 0.22 | 0.25 | 0.48 | 0.49 | 0.53 | 0.62 | 0.64 | 0.68 |

## TABLE 4.47

### Number of effective nodules of greengram

| Cropping sequence | Number of effective nodules $plant^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 18.60 | 19.00 | 19.00 | 28.20 | 28.40 | 29.80 | 21.40 | 22.00 | 23.20 |
| 2. E-M-G | 18.00 | 18.20 | 19.80 | 29.20 | 29.40 | 30.40 | 20.20 | 21.20 | 22.80 |
| 4. Jo-G-P-S | 18.80 | 20.40 | 21.40 | 31.20 | 33.40 | 35.20 | 23.40 | 24.40 | 26.40 |
| 7. G-Ra-Md | 17.80 | 21.40 | 18.20 | 28.02 | 29.20 | 31.20 | 21.20 | 22.00 | 22.80 |
| 9. M(Gi)-G-P | *(16.80) | (17.00) | (17.20) | (21.20) | (21.50) | (22.40) | (16.20) | (18.20) | (19.00) |
| | 18.20 | 18.40 | 19.20 | 27.40 | 26.40 | 28.20 | 23.40 | 21.80 | 23.20 |
| 10. E(Ci)-M-G | 17.20 | 17.60 | 18.40 | 26.40 | 23.20 | 24.40 | 22.00 | 20.00 | 22.40 |

* Intercrop value

## TABLE 4.48

### Number of effective nodules of groundnut

| Cropping sequence | Number of effective nodules $plant^{-1}$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | | 75 DAS | | | 90 DAS | | |
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 6. E-W-Gn | 136.4 | 148.8 | 164.5 | 156.6 | 172.2 | 192.2 | 239.0 | 252.2 | 261.2 | 259.4 | 246.8 | 262.4 | 210.2 | 221.0 | 228.6 |

## TABLE 4.49

### Number of effective nodules of green manure

| Cropping sequence | Number of effective nodules $plant^{-1}$ (at harvest) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 8. Gm-Ra-Rb (*Dhaincha*) | 17.80 | 24.00 | 22.40 |

## TABLE 4.50

### Dry weight of nodules of greengram

| Cropping sequence | Nodule dry weight plant$^{-1}$ (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 0.019 | 0.021 | 0.017 | 0.022 | 0.024 | 0.024 | 0.121 | 0.123 | 0.120 |
| 2. E-M-G | 0.018 | 0.017 | 0.019 | 0.023 | 0.027 | 0.026 | 0.104 | 0.117 | 0.117 |
| 4. Jo-G-P-S | 0.016 | 0.026 | 0.023 | 0.025 | 0.032 | 0.030 | 0.123 | 0.124 | 0.127 |
| 7. G-Ra-Md | 0.015 | 0.023 | 0.014 | 0.022 | 0.024 | 0.021 | 0.109 | 0.112 | 0.110 |
| 9. M(Gi)-G-P | *(0.016) | (0.015) | (0.012) | (0.016) | (0.018) | (0.016) | (0.085) | (0.013) | (0.012) |
| | 0.018 | 0.019 | 0.017 | 0.021 | 0.023 | 0.019 | 0.112 | 0.109 | 0.114 |
| 10. E(Ci)-M-G | 0.016 | 0.016 | 0.014 | 0.019 | 0.018 | 0.021 | 0.114 | 0.102 | 0.107 |

* Intercrop value

## TABLE 4.51

### Dry weight of nodules of groundnut

| Cropping sequence | Nodule dry weight plant$^{-1}$ (g) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 45 DAS | | | 60 DAS | | | 75 DAS | | | 90 DAS | | |
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 6. E-W-Gn | 0.112 | 0.127 | 0.136 | 0.129 | 0.143 | 0.161 | 0.146 | 0.154 | 0.164 | 0.173 | 0.174 | 0.176 | 0.126 | 0.127 | 0.135 |

## TABLE 4.52

### Dry weight of nodules of green manure

| Cropping sequence | Nodule dry weight plant$^{-1}$ (g) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 8. Gm-Ra-Ra (*Dhaincha*) | 0.191 | 0.245 | 0.234 |

**Plate 11 : Wheat at milk stage in sequence 6 ( 1998-1999)**

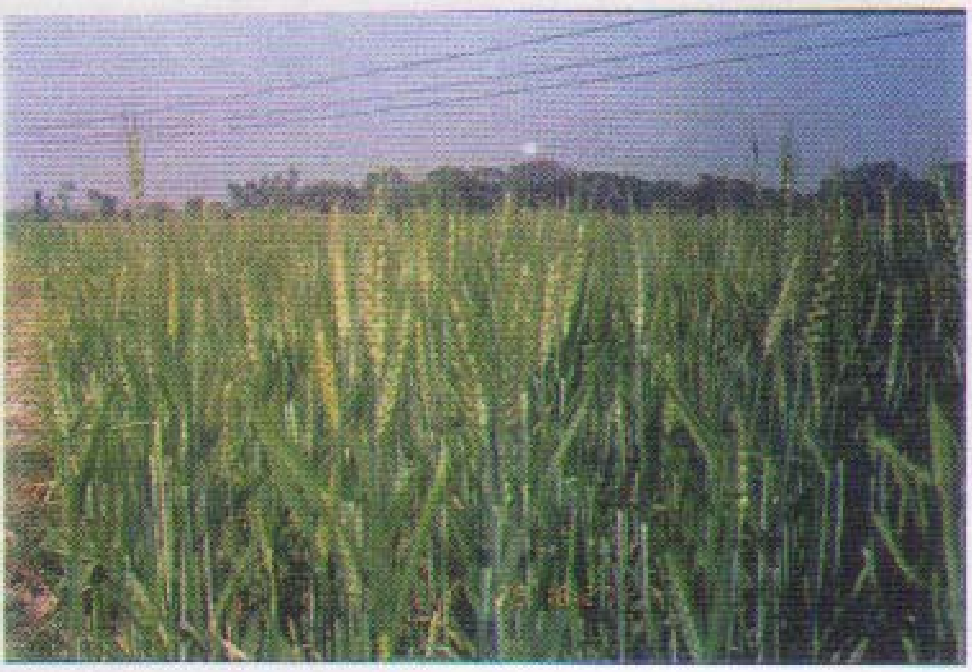


**Plate 12 : Wheat in sequence 6 at dough stage (2000-2001)**

#### 4.1.5.2.2 Dry weight of nodules of groundnut

In groundnut, the dry weight of nodules plant$^{-1}$ increased with the advancement of growth upto 75 DAS and thereafter it declined. The highest nodule dry weight plant$^{-1}$ (0.176 g) was noted at 75 DAS in 3$^{rd}$ year (Table 4.51). No adverse effect of arsenic was noted either on the nodule number or on nodule dry weight in groundnut.

#### 4.1.5.2.3 Dry weight of nodules of green manure

Nodule dry weight plant$^{-1}$ was lower than usual in the green manure crop which might be due to poor growth of the crop (Table 4.52). The highest nodule dry weight plant$^{-1}$ was noted in 2$^{nd}$ year (0.245 g).

## 4.2 Yield and harvest index (HI) of crops in different systems of cropping

### 4.2.1 Yield and harvest index of greengram

Results showed significant variation in seed yields of greengram grown in different systems of cropping (Table 4.53). That variation in yield might be due to variation in availability of soil moisture and growing condition which was more favourable when the crop was grown during the *kharif* season compared with greengram raised during pre-*kharif* and summer months as evident from comparatively higher yields of greengram in sequences 4 and 9. Greengram grown after jute in sequence 4 recorded the highest seed yields of 0.83, 0.79 and 0.80 t ha$^{-1}$ in 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ year of investigation, respectively. Intercropped greengram recorded the lowest seed yield which might be due to greater competition and suppression of growth by the dominant component, i.e., maize. Influence of the preceding crops on following greengram did not show any definite trend with regard to it's seed yield (Fig. 4). Greengram when succeeded jute in rotation (sequence 4) having the highest yield among all the sequences tried in all the years resulted from the influence of jute towards increasing the available soil nutrients. Roy (1973) earlier reported similarly.

Stover yield of greengram also showed variation in the first two years of investigation. Greengram, grown after jute in sequence 4, recorded the highest stover yield.

Harvest index was not found to vary much due to the practice of growing greengram in different systems of cropping (Table 4.53). The highest HI was noted in sequence 7 in both 1st and 3rd year of investigation (18.27and 18.00%, respectively) while in 2nd year, greengram grown in sequence 4 recorded the highest HI (17.83%). Intercropped greengram recorded the lowest HI in all the three years of experimentation.

### 4.2.2 Yield and HI of potato

Tuber yield of potato grown in different sequences resulted significant variation only in 1st year. The highest tuber yield (18.50 t $ha^{-1}$) was obtained from sequence 1 in 1st year which was at par with sequence 9 (18.41 t $ha^{-1}$). Significantly, the lowest yield in sequence 4 during 1st year was recorded resulting from the damage caused by diseases. The highest tuber yields to the tune of 18.92 and 19.66 t $ha^{-1}$, were associated with potato in sequence 9 during 2nd and 3rd year, respectively, followed by sequence 1. Growing potato in different systems of cropping seemed to have little or no impact on the tuber yield of potato on the last two years of experimentation (Table 4.54; Fig. 5). The highest haulm yield was noted in sequence 1 in all the three years of investigation with significant variation.

Harvest index of potato showed little variation. Potato in sequence 9 gave rise to comparatively higher HI in all the three years of experimentation.

### 4.2.3 Yield and harvest index of rice

The summer (*boro*) rice with different systems of cropping recorded higher grain yield than winter (*aman*) rice (Table 4.55; Fig. 6). Winter rice recorded progressive increase in yield over the years in most cases with sequence 8, *i.e.,* rice grown after the incorporation of green manure resulting in higher yields in all the years. This demonstrated the beneficial effect of green manuring on the succeeding rice crop. This was earlier reported by Mandal *et al.* (1993a and 1993b). *Boro* or summer rice in sequence 8 gave the highest grain yield in all the three years of investigation. Higher amount of DM yield resulting from the receipt of greater amount of solar radiation and longer period of bright sunshine hours in dry season gave rise to higher grain yield in summer rice compared with winter rice.

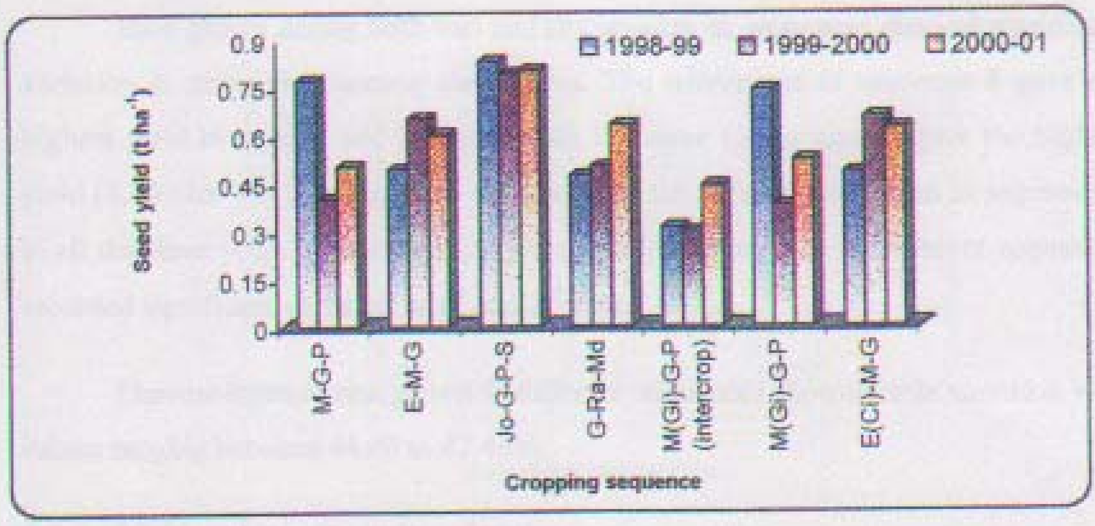



**Fig. 4 : Yield of greengram in different cropping sequences**

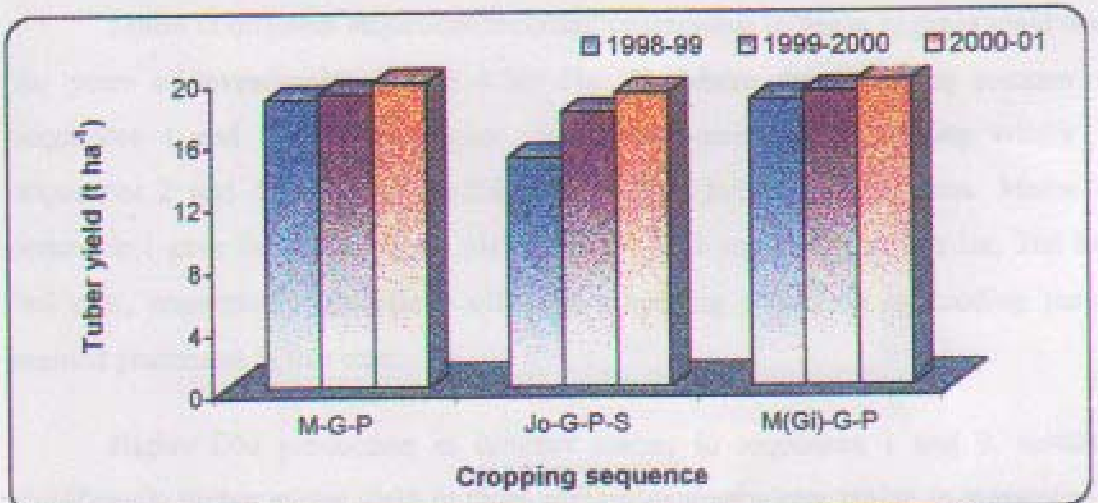



**Fig. 5 : Yield of potato in different cropping sequences**

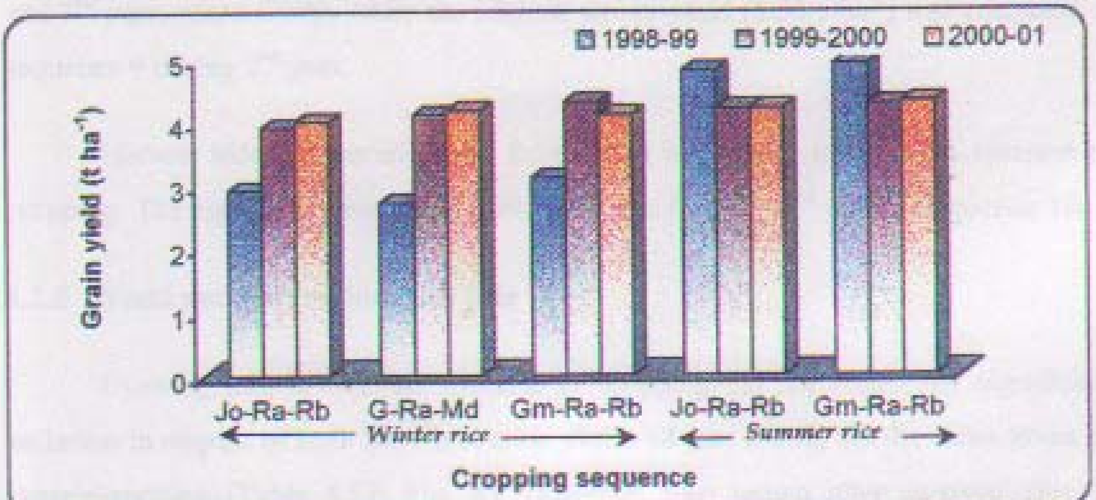



**Fig. 6 : Yield of rice in different cropping sequences**

Rice grown during both wet and dry seasons in sequences showed significant variation in straw yield among themselves. The winter rice in sequence 8 gave the highest yield in both 1st and 2nd year while the same in sequence 7 gave the highest yield (4.10 t $ha^{-1}$) in 3rd year. *Boro* rice recorded the highest straw yield in sequence 8 in all the three years of investigation. Straw yield of *boro* rice in different sequences recorded significant variation in 1st and 3rd year.

Harvest index of rice grown in different sequences showed little variation with values ranging between 44.40 to 47.44%.

### 4.2.4 Yield and harvest index of maize

Maize in different sequences recorded progressive increase in grain yield over the years of investigation (Table 4.56; Fig. 7). Maize grown during summer in sequences 1 and 9 recorded higher yields than maize grown during winter in sequences 2 and 10 with no significant variation between themselves. Maize in sequence 1 gave the highest grain yield of 4.83, 4.92 and 5.10 t $ha^{-1}$ in 1st, 2nd and 3rd year, respectively. Beneficial effect of preceding potato on succeeding maize seemed prominent in that case.

Higher DM production in summer maize, in sequences 1 and 9, resulted significantly higher stover yield in those sequences than winter maize in sequences 2 and 10.The highest stover yields of 8.49 and 8.59 t $ha^{-1}$ were noted in sequence 1 in 1st and 3rd year, respectively, while the highest stover yield (8.33 t $ha^{-1}$) was recorded in sequence 9 during 2nd year.

Harvest index of maize varied from 36.26 to 39.17% in different systems of cropping. The highest harvest index ((39.17%) was found in 3rd year in sequence 10.

### 4.2.5 Yield and harvest index of jute

Growing jute in different systems of cropping did not result any significant variation in respect of both fibre and stick yields of jute during all the three years of experimentation (Table 4.57; Fig. 8). However, jute grown after summer rice in sequence 5 gave an increasing trend towards both fibre and stick yields in all the years

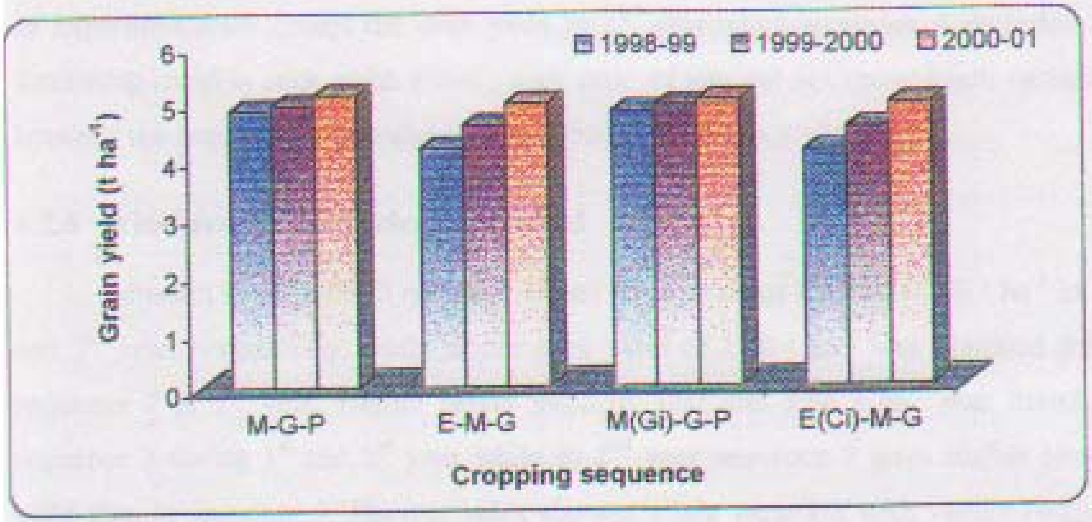



**Fig. 7 :** **Yield of maize in different cropping sequences**

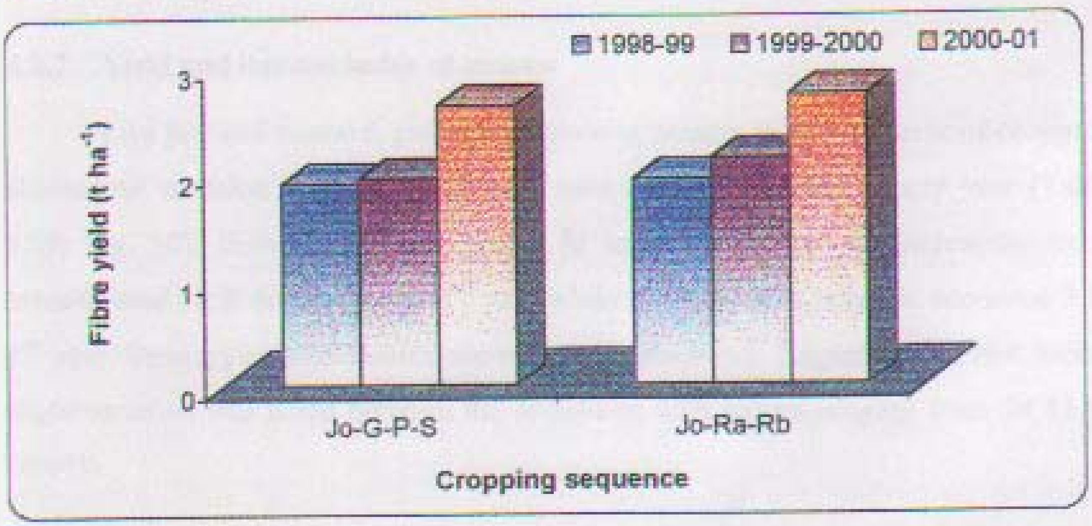



**Fig. 8 :** **Yield of jute in different cropping sequences**

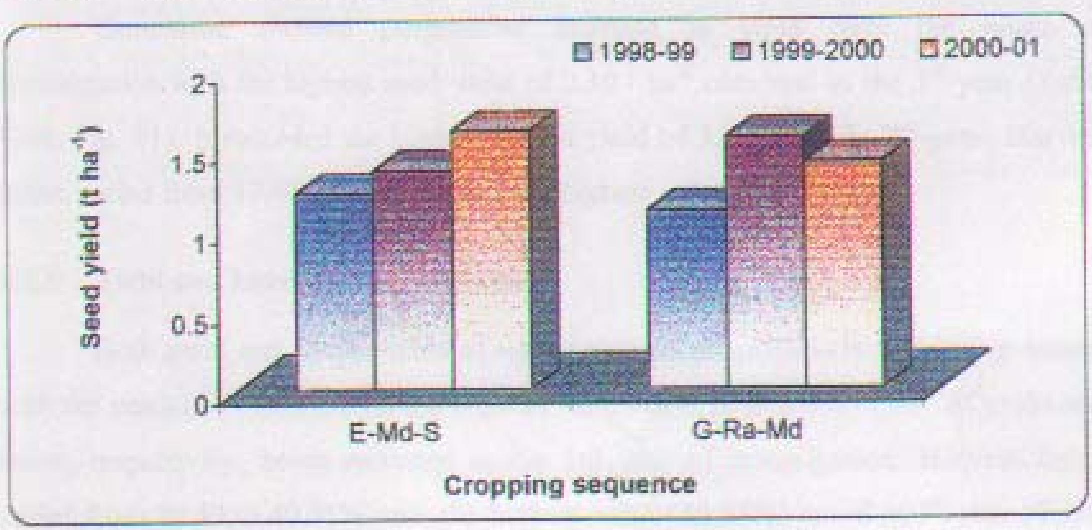



**Fig. 9 :** **Yield of mustard in different cropping sequences**

of experimentation except the stick yield in 2nd year when sequence 4 recorded an increasing trend in stick yield. Fibre : stick ratio of jute did not show much variation between the sequences with values varying from 1 : 2.51 to 1 : 2.69.

### 4.2.6 Yield and harvest index of mustard

Mustard in sequence 3 recorded higher seed yields of 1.21 and 1.60 t $ha^{-1}$ in 1st and 3rd year, respectively, while higher seed yield of 1.56 t $ha^{-1}$ was obtained from sequence 7 in 2nd year. Higher stover yield of 3.07 and 3.88 t $ha^{-1}$ was found in sequence 3 during 1st and 3rd year while in 2nd year sequence 7 gave higher stover yield than in sequence 3. Harvest index showed slight variation with values ranging between 27.53 to 29.14% (Table 4.58; Fig. 9).

### 4.2.7 Yield and harvest index of sesame

Like jute and mustard, practice of growing sesame in two systems of cropping showed no variation with respect to both seed and stover yields in any year (Table 4.59; Fig. 10). However, sesame grown in sequence 4 gave an increasing trend towards seed yield during 1st and 2nd year while the same was noted in sequence 3 in 2nd year. Stover yields of sesame showed the same trend. Regarding harvest index, slight variation was noted between the sequences with values ranging from 24.83 to 26.04%.

### 4.2.8 Yield and harvest index of groundnut

Groundnut showed progressive increase in yield over the years of investigation with the highest seed yield of 2.10 t $ha^{-1}$ obtained in the 3rd year (Table 4.60; Fig. 11). It recorded the highest haulm yield of 3.23 t $ha^{-1}$ in 2nd year. Harvest index varied from 37.68 to 40.22% with the highest value in 3rd year.

### 4.2.9 Yield and harvest index of wheat

Both grain and straw yields of wheat showed progressively increasing values with the years of cropping with the highest values of 4.10 and 6.04 t $ha^{-1}$ of grain and straw, respectively, being recorded in the 3rd year of investigation. Harvest index varied from 40.40 to 40.71% with the highest value (40.71%) noted in 1st year (Table 4.61; Fig. 12).

### 4.2.10 Yield and harvest index of elephant-foot yam

Significant variation was noted with regard to corm yields obtained by growing elephant-foot yam in different systems of cropping (Table 4.62; Fig. 13). Corm yield registered progressive increase over the years The lowest corm yield in 1st year was recorded due to poor growth and lowest DM production owing to the use of small sized corm as planting material. Sen *et al.* (1984) earlier reported the same trend of increase in corm yield of elephant-foot yam with the increase in seed size. The highest corm yield to the tune of 24.0 t $ha^{-1}$ was obtained in 1st year with sequence 6 while the highest yields of 39.2 and 40.0 t $ha^{-1}$ were recorded during the last two years of experimentation with sequence 3.

Shoot yield showed no significant variation in 1st year, while it resulted variations in other two years of cropping. The highest shoot yield of 1.56 t $ha^{-1}$ was noted in 1st year, while the highest values were 2.04 and 2.08 t $ha^{-1}$ in 2nd and 3rd year of investigation, respectively.

## 4.3 Nitrogen, phosphorus and potassium contents of crops grown in different systems of cropping

### 4.3.1 Nitrogen, phosphorus and potassium contents in greengram at harvest

Results revealed very little variation in N, P and K contents in seeds of greengram (Table 4.63) among the years. In all the years, greengram after mustard in cropping sequence 7 (G-Ra-Md) recorded the highest N, P and K contents in seed. Nitrogen content in seeds were lowest when it succeeded maize in sequences 1, 2 and 9 due to the fact that maize was a heavy feeder of nutrients. The trends were more or less similar with both P and K. N, P and K contents were lower in seeds of intercropped greengram owing to the fact that the main crop, *i.e.,* maize was a heavy feeder one.

The trends were more or less similar in case of N, P and K contents in stover also. High values of all the three nutrients were associated with greengram when it followed mustard in sequence 7 (G-Ra-Md) although the variation in nutrient contents in stover of greengram amongst the various cropping sequences were very negligible. Growing greengram in different seasons of the year were found to have little effect on it's nutrient contents.

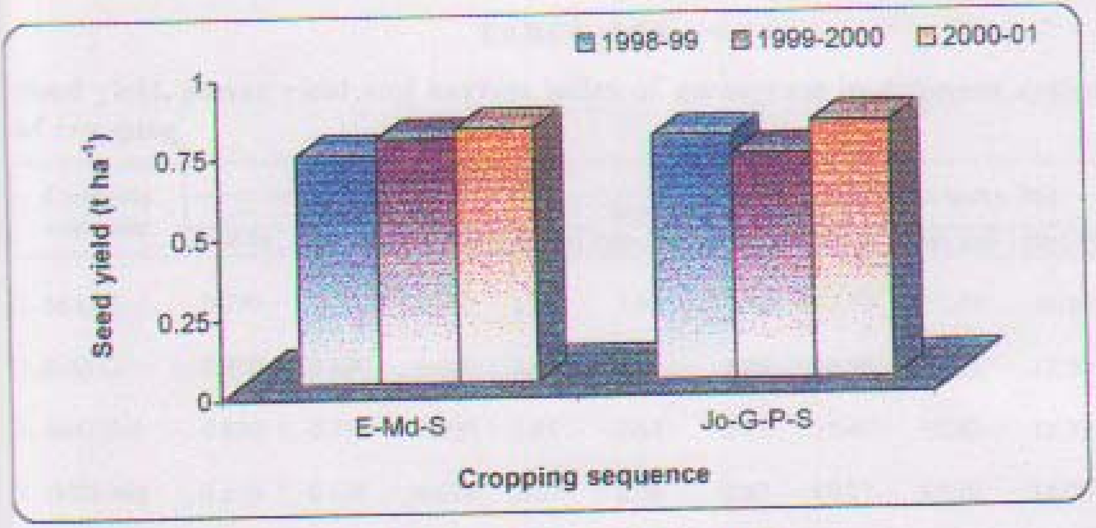



**Fig. 10 : Yield of sesame in different cropping sequences**

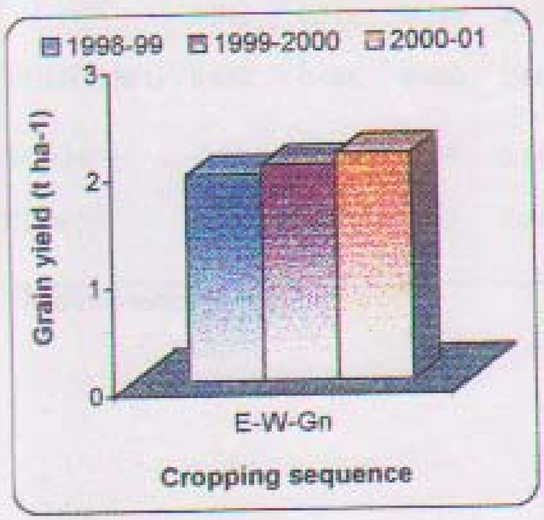



**Fig. 11 : Yield of groundnut**

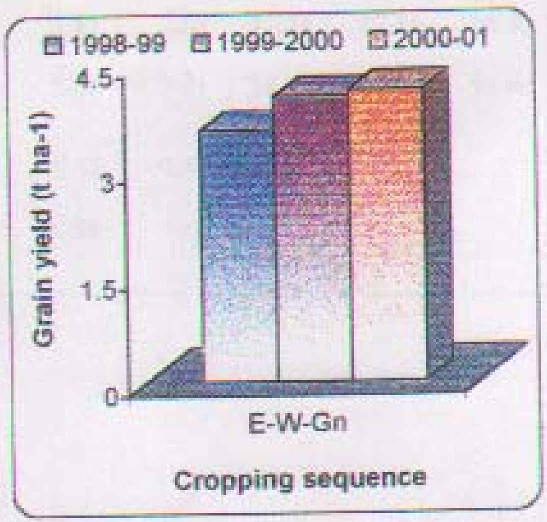



**Fig. 12 : Yield of wheat**

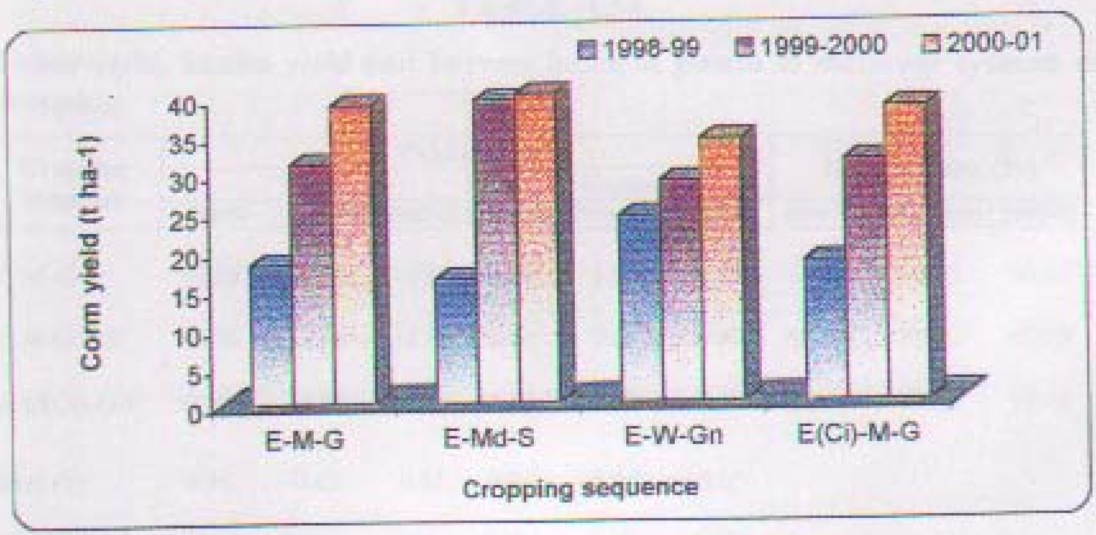



**Fig. 13 : Yield of elephant-foot yam in different cropping sequences**

## TABLE 4.53

**Seed yield, stover yield and harvest index of greengram in different systems of cropping**

| Cropping sequence | Yield (t ha$^{-1}$) | | | | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seed | | | Stover | | | | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 0.770 | 0.398 | 0.500 | 3.63 | 1.93 | 2.59 | 17.50 | 17.09 | 16.18 |
| 2. E-M-G | 0.490 | 0.650 | 0.600 | 2.43 | 3.01 | 2.88 | 16.78 | 17.75 | 17.20 |
| 4. Jo-G-P-S | 0.830 | 0.790 | 0.800 | 3.94 | 3.64 | 3.71 | 17.40 | 17.83 | 17.73 |
| 7. G-Ra-Md | 0.470 | 0.498 | 0.630 | 2.10 | 2.40 | 2.87 | 18.27 | 17.18 | 18.00 |
| 9. M(Gi)-G-P | *(0.310) | (0.296) | (0.441) | (1.64) | (1.18) | (2.18) | (15.89) | (16.66) | (16.70) |
| | 0.740 | 0.378 | 0.520 | 3.53 | 1.83 | 2.63 | 17.34 | 17.11 | 16.50 |
| 10. E(Ci)-M-G | 0.480 | 0.654 | 0.620 | 2.41 | 3.08 | 3.03 | 16.62 | 17.52 | 16.98 |
| SEm (±) | 0.03 | 0.04 | 0.03 | 0.34 | 0.32 | 0.33 | | | |
| CD at 5% | 0.09 | 0.12 | 0.09 | 1.04 | 0.98 | NS | | | |

* Intercrop value

## TABLE 4.54

**Tuber yield, haulm yield and harvest index of potato in different systems of cropping**

| Cropping sequence | Yield (t ha$^{-1}$) | | | | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tuber | | | Haulm | | | | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 18.50 | 18.90 | 19.60 | 1.89 | 1.92 | 1.98 | 90.70 | 90.73 | 90.81 |
| 4. Jo-G-P-S | 14.70 | 17.60 | 18.90 | 1.46 | 1.63 | 1.64 | 90.96 | 91.50 | 92.00 |
| 9. M(Gi)-G-P | 18.41 | 18.92 | 19.66 | 1.68 | 1.59 | 1.90 | 91.60 | 92.22 | 91.14 |
| SEm (±) | 0.44 | 0.43 | 0.51 | 0.07 | 0.04 | 0.05 | | | |
| CD at 5% | 1.720 | NS | NS | 0.274 | 0.150 | 0.190 | | | |

## TABLE 4.55

**Grain yield, straw yield and harvest index of rice in different systems of cropping**

| Cropping sequence | Grain yield (t $ha^{-1}$) | | | Straw yield (t $ha^{-1}$) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| ✪ *Aman* | | | | | | | | | |
| 5. Jo-Ra-Rb | 2.90 | 3.90 | 4.00 | 3.44 | 4.40 | 4.61 | 45.74 | 46.94 | 46.40 |
| 7. G-Ra-Md | 2.70 | 4.10 | 4.17 | 3.38 | 4.86 | 4.98 | 44.40 | 45.75 | 45.80 |
| 8. Gm-Ra-Rb | 3.09 | 4.30 | 4.10 | 3.61 | 4.96 | 4.84 | 46.11 | 46.41 | 45.82 |
| ✪ *Boro* | | | | | | | | | |
| 5. Jo-Ra-Rb | 4.80 | 4.20 | 4.20 | 5.44 | 4.82 | 4.64 | 46.82 | 46.51 | 47.44 |
| 8. Gm-Ra-Rb | 4.90 | 4.26 | 4.30 | 5.58 | 4.94 | 4.81 | 46.71 | 46.27 | 47.20 |
| SEm(±) | 0.052 | 0.043 | 0.040 | 0.042 | 0.047 | 0.050 | | | |
| CD at 5% | 0.169 | 0.140 | 0.130 | 0.130 | 0.150 | 0.160 | | | |

## TABLE 4.56

**Grain yield, stover yield and harvest index of maize in different systems of cropping**

| Cropping sequence | Grain yield (t $ha^{-1}$) | | | Stover yield (t $ha^{-1}$) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 4.83 | 4.92 | 5.10 | 8.49 | 8.28 | 8.59 | 36.26 | 37.27 | 37.23 |
| 2. E-M-G | 4.16 | 4.56 | 4.94 | 6.83 | 7.68 | 7.75 | 37.85 | 37.25 | 38.81 |
| 9. M(Gi)-G-P | 4.80 | 4.90 | 5.00 | 8.43 | 8.33 | 8.49 | 36.28 | 37.03 | 37.06 |
| 10. E(Ci)-M-G | 4.10 | 4.50 | 4.92 | 6.72 | 7.76 | 7.64 | 37.89 | 36.70 | 39.17 |
| SEm (±) | 0.040 | 0.032 | 0.034 | 0.036 | 0.031 | 0.052 | | | |
| CD at 5% | 0.16 | 0.11 | 0.11 | 0.12 | 0.10 | 0.17 | | | |

## TABLE 4.57

**Fibre yield, stick yield and fibre : stick ratio of jute in different systems of cropping**

| Cropping sequence | Fibre yield (t $ha^{-1}$) | | | Stick yield (t $ha^{-1}$) | | | Fibre : stick ratio | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 4. Jo-G-P-S | 1.87 | 1.92 | 2.60 | 4.69 | 5.04 | 6.70 | 1 : 2.51 | 1 : 2.63 | 1 : 2.58 |
| 5. Jo-Ra-Rb | 1.90 | 2.10 | 2.70 | 5.14 | 4.87 | 7.26 | 1 : 2.71 | 1 : 2.32 | 1 : 2.69 |
| 't' value | $0.65^{NS}$ | $3.05^{NS}$ | $2.19^{NS}$ | $9.89^{NS}$ | $3.73^{NS}$ | $12.31^{NS}$ | | | |

## TABLE 4.58

**Seed yield, stover yield and harvest index of mustard in different systems of cropping**

| Cropping sequence | Seed yield (t $ha^{-1}$) | | | Stover yield (t $ha^{-1}$) | | | Harvest index | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 1.21 | 1.35 | 1.60 | 3.070 | 3.370 | 3.880 | 28.24 | 28.54 | 29.14 |
| 7. G-Ra-Md | 1.10 | 1.56 | 1.40 | 2.886 | 3.780 | 3.578 | 27.53 | 29.10 | 28.11 |
| 't' value | $2.41^{NS}$ | $4.61^{NS}$ | $4.39^{NS}$ | $3.95^{NS}$ | $9.01^{NS}$ | $6.37^{NS}$ | | | |

## TABLE 4.59

**Seed yield, stover yield and harvest index of sesame in different systems of cropping**

| Cropping sequence | Seed yield (t $ha^{-1}$) | | | Stover yield (t $ha^{-1}$) | | | Harvest index | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 0.71 | 0.76 | 0.79 | 2.064 | 2.212 | 2.319 | 25.60 | 25.52 | 25.50 |
| 4. Jo-G-P-S | 0.76 | 0.70 | 0.80 | 2.282 | 2.102 | 2.276 | 24.83 | 25.11 | 26.04 |
| 't' value | $1.31^{NS}$ | $1.40^{NS}$ | $0.22^{NS}$ | $4.79^{NS}$ | $2.41^{NS}$ | $0.94^{NS}$ | | | |

## TABLE 4.60

### Grain yield, haulm yield and harvest index of groundnut

| Cropping sequence | Grain yield (t ha$^{-1}$) | | | Haulm yield (t ha$^{-1}$) | | | Harvest index | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 1.91 | 2.00 | 2.10 | 3.16 | 3.23 | 3.10 | 37.68 | 38.24 | 40.22 |

## TABLE 4.61

### Grain yield, straw yield and harvest index of wheat

| Cropping sequence | Grain yield (t ha$^{-1}$) | | | Straw yield (t ha$^{-1}$) | | | Harvest index | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 3.53 | 4.01 | 4.10 | 5.14 | 5.85 | 6.04 | 40.71 | 40.65 | 40.40 |

## TABLE 4.62

### Corm yield and shoot yield of elephant-foot yam in different systems of cropping

| Cropping sequence | Corm yield (t ha$^{-1}$) | | | Shoot yield (t ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 2. E-M-G | 18.0 | 31.00 | 38.70 | 1.56 | 1.87 | 1.78 |
| 3. E-Md-S | 16.0 | 39.20 | 40.00 | 1.54 | 2.04 | 2.08 |
| 6. E-W-Gn | 24.0 | 28.51 | 34.00 | 1.42 | 1.60 | 1.63 |
| 10. E(Ci)-M-G | 18.1 | 31.16 | 38.00 | 1.50 | 1.91 | 2.01 |
| SEm (±) | 1.46 | 1.10 | 1.49 | 0.045 | 0.10 | 0.094 |
| CD at 5% | 5.05 | 3.80 | 5.15 | NS | 0.34 | 0.32 |

### 4.3.2 Nitrogen, phosphorus and potassium contents in potato at harvest

Little variation was noted on N, P and K contents in tuber and haulm of potato grown in various cropping sequences; although the values increased slightly in both tuber and haulm over the three years period of experimentation. Potato, grown after greengram in sequence 4 (Jo-G-P-S), had higher N, P and K contents in both tuber and haulm in most cases. N content in haulm was slightly more than in tuber while K content was lower. However, contents of N, P and K were found to be normal suggesting no adverse effect of arsenic on crop growth and corresponding nutrient uptake (Table 4.64).

### 4.3.3 Nitrogen, phosphorus and potassium contents in rice at harvest

In rice, N, P and K contents in both grain and straw showed little variation among the different cropping sequences. Nutrient contents in grain were slightly higher in the 3rd year of cropping. However, in case of straw, contents were slightly higher in 1st year. Summer rice recorded higher N, P and K contents, in both grain and straw in all the 3 years compared with the wet season rice (*aman*) which might be due to better utilisation of photosynthates in the former crop. Wet season rice grown after greengram in cropping sequence 7 recorded slightly higher contents of N, P and K as compared to the same rice crop tried in other sequences (Table 4.65).

### 4.3.4 Nitrogen, phosphorus and potassium contents in maize at harvest

Results presented in Table 4.66, indicating N, P and K contents in maize in different cropping sequences in three consecutive years, showed very little variation in both grain and stover. N and P contents in grain were higher than in stover while K content was higher in stover. Nutrient contents were slightly higher in summer maize than in winter maize.

### 4.3.5 Nitrogen, phosphorus and potassium contents in jute at harvest (in whole plant)

Jute showed very little variation in N, P and K contents among the years as well as between the two cropping sequences, *i.e.*, there was no effect of preceding crops on nutrient contents in jute. N content was higher than both P and K. In most cases, jute grown after sesame (cropping sequence 4) had higher nutrient contents than after summer rice in cropping sequence 5 (Table 4.67).

### 4.3.6 Nitrogen, phosphorus and potassium contents in mustard at harvest

Results presented in Table 4.68 showed higher N content in seeds of mustard than in stover while it was reversed in case of K. Though there was very little variation in N, P and K contents over the years in both seed and in stover, however, it showed a gradual increase of nutrient contents over the years. Mustard, grown after wet season rice, recorded high values of nutrient contents in both seed and straw (sequence 7) than the crop grown after elephant-foot yam (sequence 3) which might be due to better availability of nutrients in soil after rice.

### 4.3.7 Nitrogen, phosphorus and potassium contents in sesame at harvest

Sesame had high contents of N in both seed and stover. It showed gradual increase in nutrient contents over the years in both seeds and in stover. The stalk had very high values of K content. Sesame grown after potato in cropping sequence 4 showed higher values of N, P and K contents in both seed and stover than sesame grown after mustard in cropping sequence 3 (Table 4.69).

### 4.3.8 Nitrogen, phosphorus and potassium contents in groundnut at harvest

Results showed that N content was very high in groundnut kernel while haulm had high content of K. Very little variation was noted in N, P and K contents among the years (Table 4.70).

### 4.3.9 Nitrogen, phosphorus and potassium contents in wheat at harvest

N and P contents were higher in wheat grain than in straw while straw had very high K contents (Table 4.71). Little variation was noted with respect to nutrient contents among the years of cropping in both grain and straw.

### 4.3.10 Nitrogen, phosphorus and potassium contents in elephant-foot yam at harvest

In case of elephant-foot yam, N, P and K contents were high in shoot than in corm. It showed gradual increase in nutrient contents in both corm and shoot over the

## TABLE 4.63

## Nutrient content of greengram at harvest in different systems of cropping

| Cropping sequence | Nutrient content in seed (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 2.54 | 2.61 | 2.51 | 0.153 | 0.171 | 0.163 | 1.60 | 1.53 | 1.42 |
| 2. E-M-G | 2.34 | 2.32 | 2.42 | 0.173 | 0.161 | 0.157 | 1.49 | 1.49 | 1.37 |
| 4. Jo-G-P-S | 2.41 | 2.43 | 2.31 | 0.170 | 0.164 | 0.152 | 1.52 | 1.51 | 1.40 |
| 7. G-Ra-Md | 2.73 | 2.84 | 2.80 | 0.187 | 0.189 | 0.184 | 1.66 | 1.65 | 1.76 |
| 9. M(Gi)-G-P | *(2.59) | (2.10) | (2.48) | (0.153) | (0.168) | (0.171) | (1.44) | (1.43) | (1.51) |
| | 2.43 | 2.24 | 2.50 | 0.162 | 0.159 | .149 | 1.39 | 1.41 | 1.42 |
| 10. E(Ci)-M-G | 2.51 | 2..23 | 2.47 | 0.170 | 0.174 | 0.162 | 1.51 | 1.46 | 1.41 |
| | **Nutrient content in stover (%)** | | | | | | | | |
| 1. M-G-P | 1.581 | 1.701 | 1.801 | 0.137 | 0.140 | 0.147 | 0.742 | 0.788 | 0.731 |
| 2. E-M-G | 1.643 | 1.782 | 1.783 | 0.147 | 0.137 | 0.136 | 0.816 | 0.770 | 0.719 |
| 4. Jo-G-P-S | 1.670 | 1.743 | 1.647 | 0.135 | 0.130 | 0.130 | 0.762 | 0.765 | 0.720 |
| 7. G-Ra-Md | 1.863 | 1.831 | 1.519 | 0.159 | 0.157 | 0.150 | 0.821 | 0.861 | 0.837 |
| 9. M(Gi)-G-P | *(1.594) | (1.695) | (1.806) | (0.141) | (0.132) | (0.139) | (0.817) | (0.783) | (0.774) |
| | 1.641 | 1.721 | 1.780 | 0.142 | 0.136 | 0.142 | 0.731 | 0.772 | 0.724 |
| 10. E(Ci)-M-G | 1.687 | 1.632 | 1.794 | 0.143 | 0.138 | 0.132 | 0.802 | 0.763 | 0.740 |

*Intercrop value

## TABLE 4.64

## Nutrient content of potato at harvest in different systems of cropping

| Cropping sequence | Nutrient content in tuber (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 1.480 | 1.466 | 1.540 | 0.281 | 0.280 | 0.291 | 2.421 | 2.443 | 2.461 |
| 4. Jo-G-P-S | 1.501 | 1.532 | 1.562 | 0.273 | 0.291 | 0.302 | 2.523 | 2.428 | 2.472 |
| 9. M(Gi)-G-P | 1.487 | 1.473 | 1.485 | 0.270 | 0.276 | 0.286 | 2.434 | 2.419 | 2.470 |
| | Nutrient content in haulm (%) | | | | | | | | |
| 1. M-G-P | 1.184 | 1.193 | 1.214 | 0.282 | 0.285 | 0.288 | 1.873 | 1.820 | 1.857 |
| 4. Jo-G-P-S | 1.190 | 1.207 | 1.215 | 0.284 | 0.290 | 0.290 | 1.889 | 1.904 | 1.910 |
| 9. M(Gi)-G-P | 1.189 | 1.187 | 1.206 | 0.278 | 0.281 | 0.292 | 1.868 | 1.843 | 1.864 |

## TABLE 4.65

## Nutrient content of rice at harvest in different systems of cropping

| Cropping sequence | Nutrient content in grain (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| ✪ *Aman* | | | | | | | | | |
| 5. Jo-Ra-Rb | 1.061 | 1.043 | 1.159 | 0.340 | 0.332 | 0.354 | 0.346 | 0.360 | 0.380 |
| 7. G-Ra-Md | 1.504 | 1.622 | 1.704 | 0.364 | 0.382 | 0.384 | 0.380 | 0.398 | 0.378 |
| 8. Gm-Ra-Rb | 1.041 | 1.256 | 1.252 | 0.341 | 0.350 | 0.342 | 0.338 | 0.373 | 0.384 |
| ✪ *Boro* | | | | | | | | | |
| 5. Jo-Ra-Rb | 1.242 | 1.253 | 1.263 | 0.354 | 0.359 | 0.370 | 0.413 | 0.419 | 0.424 |
| 8. Gm-Ra-Rb | 1.262 | 1.263 | 1.241 | 0.364 | 0.362 | 0.354 | 0.432 | 0.442 | 0.401 |
| | Nutrient content in straw (%) | | | | | | | | |
| ✪ *Aman* | | | | | | | | | |
| 5. Jo-Ra-Rb | 0.412 | 0.381 | 0.399 | 0.143 | 0.150 | 0.154 | 1.521 | 1.540 | 1.520 |
| 7. G-Ra-Md | 0.432 | 0.463 | 0.493 | 0.169 | 0.178 | 0.180 | 1.692 | 1.723 | 1.839 |
| 8. Gm-Ra-Rb | 0.407 | 0.424 | 0.406 | 0.147 | 0.156 | 0.162 | 1.473 | 1.519 | 1.541 |
| ✪ *Boro* | | | | | | | | | |
| 5. Jo-Ra-Rb | 0.451 | 0.460 | 0.454 | 0.172 | 0.181 | 0.179 | 1.621 | 1.632 | 1.700 |
| 8. Gm-Ra-Rb | 0.442 | 0.461 | 0.443 | 0.181 | 0.174 | 0.170 | 1.634 | 1.617 | 1.637 |

## TABLE 4.66

### Nutrient content of maize at harvest in different systems of cropping

| Cropping sequence | Nutrient content in grain (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 1.483 | 1.482 | 1.502 | 0.248 | 0.257 | 0.244 | 0.430 | 0.438 | 0.426 |
| 2. E-M-G | 1.466 | 1.440 | 1.463 | 0.239 | 0.250 | 0.234 | 0.423 | 0.430 | 0.413 |
| 9. M(Gi)-G-P | 1.447 | 1.463 | 1.445 | 0.232 | 0.240 | 0.231 | 0.414 | 0.413 | 0.420 |
| 10. E(Ci)-M-G | 1.490 | 1.475 | 1.475 | 0.221 | 0.247 | 0.240 | 0.406 | 0.421 | 0.422 |
| | **Nutrient content in stover (%)** | | | | | | | | |
| 1. M-G-P | 0.702 | 0.729 | 0.663 | 0.204 | 0.193 | 0.175 | 1.104 | 1.096 | 1.065 |
| 2. E-M-G | 0.673 | 0.703 | 0.641 | 0.176 | 0.174 | 0.154 | 1.085 | 1.072 | 1.052 |
| 9. M(Gi)-G-P | 0.653 | 0.700 | 0.652 | 0.162 | 0.185 | 0.163 | 1.072 | 1.081 | 1.060 |
| 10. E(Ci)-M-G | 0.670 | 0.679 | 0.632 | 0.171 | 0.165 | 0.151 | 1.093 | 1.075 | 1.043 |

## TABLE 4.67

### Nutrient content of jute at harvest in different systems of cropping

| Cropping sequence | Nutrient content in jute plant (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 4. Jo-G-P-S | 0.341 | 0.327 | 0.352 | 0.180 | 0.194 | 0.203 | 0.047 | 0.048 | 0.050 |
| 5. Jo-Ra-Rb | 0.332 | 0.331 | 0.348 | 0.189 | 0.183 | 0.195 | 0.048 | 0.046 | 0.043 |

## TABLE 4.68

### Nutrient content of mustard at harvest in different systems of cropping

| Cropping sequence | Nutrient content in seed (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 2.890 | 2.941 | 2.931 | 0.610 | 0.642 | 0.631 | 1.140 | 1.069 | 1.082 |
| 7. G-Ra-Md | 3.140 | 3.100 | 3.190 | 0.664 | 0.640 | 0.653 | 1.187 | 1.170 | 1.187 |
| | **Nutrient content in stover (%)** | | | | | | | | |
| 3. E-Md-S | 0.342 | 0.340 | 0.343 | 0.116 | 0.121 | 0.123 | 1.241 | 1.291 | 1.249 |
| 7. G-Ra-Md | 0.349 | 0.359 | 0.348 | 0.119 | 0.139 | 0.124 | 1.343 | 1.360 | 1.332 |

## TABLE 4.69

### Nutrient content of sesame at harvest in different systems of cropping

| Cropping sequence | Nutrient content in seed (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 2.810 | 2.931 | 3.142 | 0.540 | 0.561 | 0.582 | 0.735 | 0.731 | 0.762 |
| 4. Jo-G-P-S | 2.904 | 3.012 | 3.073 | 0.542 | 0.554 | 0.563 | 0.722 | 0.753 | 0.752 |
| | Nutrient content in stover (%) | | | | | | | | |
| 3. E-Md-S | 1.982 | 2.052 | 2.071 | 0.213 | 0.232 | 0.242 | 1.502 | 1.563 | 1.554 |
| 4. Jo-G-P-S | 2.041 | 2.073 | 2.034 | 0.240 | 0.253 | 0.264 | 1.523 | 1.585 | 1.579 |

## TABLE 4.70

### Nutrient content of groundnut at harvest

| Cropping sequence | Nutrient content in kernel (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 3.451 | 3.282 | 3.310 | 0.490 | 0.420 | 0.421 | 0.442 | 0.454 | 0.484 |
| | Nutrient content in haulm (%) | | | | | | | | |
| 6. E-W-Gn | 0.821 | 0.812 | 0.804 | 0.260 | 0.239 | 0.245 | 0.624 | 0.612 | 0.601 |

## TABLE 4.71

### Nutrient content of wheat at harvest

| Cropping sequence | Nutrient content in grain (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 1.282 | 1.301 | 1.305 | 0.382 | 0.430 | 0.412 | 0.613 | 0.634 | 0.655 |
| | Nutrient content in straw (%) | | | | | | | | |
| 6. E-W-Gn | 0.482 | 0.476 | 0.469 | 0.222 | 0.212 | 0.203 | 1.225 | 1.237 | 1.242 |

## TABLE 4.72

**Nutrient content of elephant-foot yam at harvest in different systems of cropping**

| Cropping sequence | Nutrient content in corm (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 2. E-M-G | 1.010 | 1.010 | 1.083 | 0.542 | 0.548 | 0.564 | 1.441 | 1.462 | 1.472 |
| 3. E-Md-S | 1.013 | 1.006 | 1.068 | 0.559 | 0.556 | 0.554 | 1.460 | 1.506 | 1.491 |
| 6. E-W-Gn | 1.005 | 1.080 | 1.082 | 0.556 | 0.552 | 0.540 | 1.445 | 1.459 | 1.507 |
| 10. E(Ci)-M-G | 1.012 | 1.082 | 1.086 | 0.550 | 0.550 | 0.541 | 1.460 | 1.600 | 1.490 |
| | **Nutrient content in shoot (%)** | | | | | | | | |
| 2. E-M-G | 2.607 | 2.582 | 2.412 | 0.641 | 0.642 | 0.651 | 2.381 | 2.360 | 2.320 |
| 3. E-Md-S | 2.605 | 2.580 | 2.438 | 0.643 | 0.651 | 0.643 | 2.379 | 2.380 | 2.308 |
| 6. E-W-Gn | 2.302 | 2.596 | 2.520 | 0.641 | 0.659 | 0.649 | 2.375 | 2.396 | 2.345 |
| 10. E(Ci)-M-G | 2.614 | 2.575 | 2.406 | 0.642 | 0.640 | 0.656 | 2.387 | 2.398 | 2.361 |

## TABLE 4.73

**Nutrient content of green manure at harvest**

| Cropping sequence | Nutrient content in whole plant (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 8. Gm-Ra-Rb | 3.502 | 3.468 | 3.427 | 0.263 | 0.259 | 0.255 | 1.412 | 1.401 | 1.394 |

## TABLE 4.74

**Nutrient content of cowpea at harvest**

| Cropping sequence | Nutrient content in seed (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 10. E(Ci)-M-G | 1.48 | 1.26 | 1.41 | 0.121 | 0.101 | 0.116 | 1.20 | 1.26 | 1.12 |
| | **Nutrient content in biomass (%)** | | | | | | | | |
| 10. E(Ci)-M-G | 0.41 | 0.37 | 0.38 | 0.102 | 0.113 | 0.115 | 0.68 | 0.62 | 0.64 |

**Plate 13 : Plots under crop cafeteria experiment with potato in sequence 1 (2000-2001)**

**Plate 14 : Harvesting of potato in progress**

years in most cases (Table 4.72). High N content in corm was found when cowpea was grown as intercrop alongwith it in sequence 10. Systems of cropping was found to have no impact on nutrient contents in both corm and shoot.

#### 4.3.11 Nitrogen, phosphorus and potassium contents in green manure at harvest

Green manure showed very high values of N and K contents in plant while P content was low. High values of N, P and K contents were found during 1$^{st}$ year which might be due to lower plant population (Table 4.73).

#### 4.3.12 Nitrogen, phosphorus and potassium contents in cowpea at harvest

Nitrogen content was high in seeds of cowpea than in the biomass. In general, P and K contents were low in both seeds and biomass (Table 4.74). Little variation was noted in nutrient contents among the years in both seed and biomass.

## 4.4 Uptake of nutrients

### 4.4.1 Nutrient uptake by crops in different systems of cropping

#### 4.4.1.1 Nutrient uptake by greengram

It was apparent that different systems of cropping resulted significant variation in N, P and K uptake by greengram. Greengram, grown after jute, resulted the highest uptake of N in all the years. Comparatively higher N uptake was noted when it was grown after maize (sequence 1) than when grown after mustard (sequence 7). Intercropped greengram exhibited lower N uptake in all the three years of cropping which might had resulted from heavy uptake by the main crop, *i.e.,* maize (Table 4.75).

Similar trend was noted in case of both P and K. The highest amounts of P and K uptake were found in greengram grown after jute (sequence 4). Uptake of nutrients by greengram seemed to be in accordance with the yields of the crop rather than it's content. Variation was more in K uptake by greengram with different systems of cropping as compared to N and K.

#### 4.4.1.2 Nutrient uptake by potato

Potato showed higher amount of K uptake compared with N; while uptake of P was the lowest (Table 4.76). It showed significant variation towards N and K uptakes in different systems of cropping while P uptake was not significant. Potato grown after greengram in sequence 1 showed higher amount of uptake of N, P and K in almost all the three years of experimentation. N uptake was relatively lower with sequence 4 in 1$^{st}$ year which was due to lower yield. High K content in both haulm and tuber gave rise to higher K uptake than N.

#### 4.4.1.3 Nutrient uptake by rice

Summer (*boro*) rice showed higher uptake of N, P and K than winter rice in various systems of cropping during all the three years of experimentation (Table 4.77). The variation in uptake was possible due to better utilisation of resources resulting in higher yields in summer as compared to winter rice. Winter rice grown after greengram in sequence 7 showed higher uptake of both N and K during all the three years of investigation in comparison with other sequences.

Summer rice, grown in sequence 8 (Gm-Ra-Rd), recorded slightly higher uptake of all the nutrients which might be due to better availability of soil nutrients caused by incorporation of green manure.

#### 4.4.1.4 Nutrient uptake by maize

Variations were noted towards the uptake of nutrients by maize in different systems of cropping during all the three years of investigation. Maize grown after potato in sequence 1, *i.e.,* summer maize resulted in higher amount of uptake than winter maize grown after elephant-foot yam in sequence 2. Higher nutrient uptake in summer maize was due to higher yields rather than nutrient contents. Intercropped greengram with summer maize (sequence 9) gave rise slightly to less uptake of nutrients than sole summer maize (sequence 1). Phosphorus uptake was less compared with both N and K (Table 4.78).

#### 4.4.1.5 Nutrient uptake by jute

Jute in different systems of cropping resulted little variation towards uptake in nutrients (Table 4.79). Jute in sequence 5 (Jo-Ra-Rb) had higher uptake of N, P and K in all the three years than in sequence 4 (Jo-G-P-S). Uptake of all the nutrients was higher in 3rd year in sequence 5 which was due to the production of higher amount of biomass at harvest.

#### 4.4.1.6 Nutrient uptake by mustard

Mustard when grown after rice in sequence 7 resulted increase in uptake than the crop grown after elephant-foot yam in sequence 3. Lower uptake of nutrients in sequence 3 might be due to higher uptake of nutrients by preceding elephant-foot yam in sequence 3 than rice in sequence 7 (Table 4.80).

#### 4.4.1.7 Nutrient uptake by sesame

Nutrient uptake by sesame in different systems of cropping showed no significant variation during all the three years of cropping (Table 4.81).No definite trend of superiority seemed evident between the sequences with regard to uptake of nutrients. This variation in uptake of nutrients was seen in accordance with yield rather than with nutrient contents.

#### 4.4.1.8 Nutrient uptake by groundnut

Nitrogen uptake by groundnut was higher than both P and K which was due to higher N content in both kernel and haulm. Higher N and P uptakes were noted in 3rd year while K uptake by groundnut showed the highest value in 2nd year (Table 4.82).

#### 4.4.1.9 Nutrient uptake by wheat

Potassium uptake by wheat showed higher values than N and P. Little variation was noted in N, P and K uptakes by groundnut among the three years of cropping (Table 4.83).

#### 4.4.1.10 Nutrient uptake by elephant-foot yam

Significant variation was noted towards the uptake of nutrients by elephant-foot yam due to the different systems of cropping in all the three years of experimentation (Table 4.84). Variation in nutrient uptake among the years was due to variation in yield rather than nutrient content. Elephant-foot yam, grown after greengram in sequence 10, recorded the highest uptake of N in 3rd year while the

## TABLE 4.75

**Nutrient (N, P and K) uptake by greengram with different systems of cropping**

| Cropping sequence | Nutrient uptake (kg ha$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 76.95 | 43.22 | 59.20 | 6.15 | 3.38 | 4.62 | 39.25 | 21.30 | 26.03 |
| 2. E-M-G | 51.39 | 68.72 | 65.87 | 4.42 | 5.17 | 4.86 | 27.13 | 32.86 | 28.93 |
| 4. Jo-G-P-S | 85.80 | 82.64 | 79.58 | 6.73 | 6.03 | 6.04 | 42.64 | 39.78 | 37.91 |
| 7. G-Ra-Md | 51.95 | 57.10 | 61.23 | 4.20 | 4.70 | 5.58 | 25.04 | 28.87 | 35.40 |
| 9. M(Gi)-G-P | *(34.17) | (26.22) | (50.31) | (2.79) | (2.05) | (3.78) | (17.86) | (13.47) | (23.53) |
| | 75.91 | 39.96 | 59.81 | 6.21 | 3.09 | 4.51 | 36.09 | 19.46 | 26.43 |
| 10. E(Ci)-M-G | 52.70 | 64.85 | 69.67 | 4.26 | 5.39 | 5.00 | 26.58 | 33.05 | 31.16 |
| SEm (±) | 0.69 | 0.77 | 0.51 | 0.43 | 0.41 | 0.40 | 0.54 | 0.45 | 0.74 |
| CD at 5% | 2.12 | 2.37 | 1.57 | 1.32 | 1.26 | 1.23 | 1.66 | 1.39 | 2.27 |

* Intercrop value

## TABLE 4.76

**Nutrient (N, P and K) uptake by potato with different systems of cropping**

| Cropping sequence | Nutrient uptake (kg ha$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 81.28 | 74.36 | 83.74 | 16.51 | 15.30 | 160.96 | 131.76 | 120.69 | 132.21 |
| 4. Jo-G-P-S | 59.85 | 72.83 | 77.83 | 11.87 | 14.82 | 15.96 | 98.98 | 115.29 | 123.04 |
| 9. M(Gi)-G-P | 76.04 | 74.85 | 78.45 | 14.85 | 14.96 | 16.24 | 123.14 | 121.23 | 127.79 |
| SEm (±) | 1.28 | 0.43 | 0.41 | 2.10 | 0.44 | 0.43 | 0.54 | 0.43 | 0.61 |
| CD at 5% | 5.02 | 1.68 | 1.60 | NS | NS | NS | 2.51 | 1.68 | 2.39 |

## TABLE 4.77

### Nutrient (N, P and K) uptake by rice with different systems of cropping

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| ✪ *Aman* | | | | | | | | | |
| 5. Jo-Ra-Rb | 44.94 | 57.44 | 64.75 | 14.78 | 19.55 | 21.26 | 62.36 | 81.80 | 85.27 |
| 7. G-Ra-Md | 54.66 | 89.00 | 95.50 | 15.53 | 24.31 | 24.97 | 67.44 | 100.04 | 115.34 |
| 8. Gm-Ra-Rb | 46.86 | 75.04 | 70.98 | 15.84 | 22.79 | 21.86 | 63.62 | 91.38 | 90.33 |
| ✪ *Boro* | | | | | | | | | |
| 5. Jo-Ra-Rb | 84.15 | 75.09 | 74.11 | 26.35 | 23.80 | 23.85 | 108.01 | 96.26 | 96.69 |
| 8. Gm-Ra-Rb | 86.50 | 76.58 | 75.79 | 27.94 | 24.02 | 23.72 | 112.35 | 98.71 | 96.34 |
| SEm (±) | 1.28 | 2.48 | 1.41 | 1.04 | 1.20 | 0.43 | 2.03 | 3.76 | 1.76 |
| CD at 5% | 4.17 | 8.08 | 4.59 | 3.89 | 3.91 | 1.40 | 6.62 | 12.26 | 5.73 |

## TABLE 4.78

### Nutrient (N, P and K) uptake by maize with different systems of cropping

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 1. M-G-P | 131.23 | 133.28 | 133.56 | 29.30 | 28.62 | 27.48 | 114.50 | 112.30 | 113.21 |
| 2. E-M-G | 106.95 | 119.65 | 121.67 | 21.96 | 24.76 | 23.45 | 91.70 | 101.94 | 101.85 |
| 9. M(Gi)-G-P | 124.50 | 130.00 | 127.60 | 24.79 | 27.17 | 25.39 | 110.24 | 110.28 | 110.99 |
| 10. E(Ci)-M-G | 106.11 | 119.07 | 120.85 | 20.55 | 23.92 | 23.34 | 90.10 | 102.37 | 100.46 |
| SEm (±) | 1.37 | 1.75 | 1.45 | 1.14 | 0.63 | 0.85 | 1.18 | 0.99 | 0.84 |
| CD at 5% | 4.72 | 6.03 | 4.99 | 3.92 | 2.17 | 2.92 | 4.06 | 3.41 | 2.89 |

**TABLE 4.79**

**Nutrient (N, P and K) uptake by jute with different systems of cropping**

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 4. Jo-G-P-S | 36.41 | 37.86 | 39.52 | 19.22 | 22.47 | 22.76 | 5.01 | 5.55 | 5.61 |
| 5. Jo-Ra-Rb | 39.07 | 37.17 | 47.76 | 22.24 | 20.54 | 32.37 | 5.64 | 5.16 | 7.13 |
| 't' value | 4.31 NS | 1.11 NS | 13.36 NS | 4.89 NS | 3.13 NS | 15.58 NS | 1.02 NS | 0.63 NS | 2.46 NS |

**TABLE 4.80**

**Nutrient (N, P and K) uptake by mustard with different systems of cropping**

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 35.47 | 51.16 | 60.20 | 10.94 | 12.74 | 14.87 | 51.89 | 57.94 | 65.77 |
| 7. G-Ra-Md | 44.61 | 61.93 | 57.14 | 10.73 | 15.23 | 13.16 | 52.80 | 69.65 | 64.26 |
| 't' value | 14.82 NS | 17.47 NS | 15.99 NS | 0.34 NS | 4.03 NS | 2.77 NS | 2.14 NS | 18.99 NS | 2.44 NS |

**TABLE 4.81**

**Nutrient (N, P and K) uptake by sesame with different systems of cropping**

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 3. E-Md-S | 60.86 | 67.67 | 72.85 | 8.23 | 9.40 | 10.21 | 36.22 | 40.13 | 42.06 |
| 4. Jo-G-P-S | 68.65 | 64.66 | 70.88 | 9.60 | 9.20 | 10.51 | 40.24 | 38.59 | 41.95 |
| 't' value | 12.36 NS | 4.88 NS | 3.19 NS | 2.22 NS | 1.12 NS | 0.48 NS | 6.52 NS | 2.49 NS | 0.17 NS |

## TABLE 4.82

### Nutrient (N, P and K) uptake by groundnut

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 91.85 | 91.80 | 94.51 | 16.02 | 17.75 | 16.43 | 28.15 | 28.84 | 28.70 |

## TABLE 4.83

### Nutrient (N, P and K) uptake by wheat

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 6. E-W-Gn | 70.02 | 80.01 | 81.82 | 24.89 | 29.64 | 29.15 | 84.59 | 97.78 | 101.86 |

## TABLE 4.84

### Nutrient (N, P and K) uptake by elephant-foot yam with different systems of cropping

| Cropping sequence | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 | 1998-99 | 1999-2000 | 2000-01 |
| 2. E-M-G | 94.49 | 127.36 | 155.88 | 38.87 | 54.90 | 70.40 | 113.94 | 158.60 | 194.81 |
| 3. E-Md-S | 74.30 | 155.74 | 159.85 | 30.45 | 60.27 | 69.98 | 88.58 | 202.91 | 200.38 |
| 6. E-W-Gn | 94.48 | 110.00 | 137.71 | 43.20 | 45.53 | 58.30 | 122.59 | 130.83 | 172.35 |
| 10. E(Ci)-M-G | 89.57 | 133.04 | 162.17 | 36.78 | 54.64 | 79.87 | 108.06 | 169.40 | 203.69 |
| SEm (±) | 0.68 | 0.88 | 0.54 | 0.43 | 0.56 | 0.46 | 0.84 | 0.32 | 0.62 |
| CD at 5% | 2.35 | 3.04 | 1.86 | 1.48 | 1.93 | 1.59 | 2.90 | 3.18 | 2.14 |

**Plate 15 : Sesame in sequence 3 (2000-2001)**

**Plate 16 : Sesame at flowering stage in sequence 4 (1999-2000)**

highest values of N uptake were noted in sequence 3 and 2, respectively, in 2nd and 1st year. In case of P uptake, sequence 6 (E-W-Gn) recorded the highest uptake in 1st year, sequence 3 (E-Md-S) in 2nd year while sequence 10 recorded the highest value during 3rd year. The highest K uptake was noted in sequence 6 in 1st year, in sequence 3 during 2nd year and in sequence 10 during the 3rd year of investigation.

### 4.4.2 Nutrient uptake by the different systems of cropping

#### 4.4.2.1 Nitrogen uptake by the different systems of cropping

Results summarised in Table 4.85 and Fig. 14 showed significant variation in total N uptake by the different systems of cropping in all the three years of experimentation. The variation was caused mainly due to differential uptake by the component crops in sequences.

In 1st year, sequence 9 recorded the highest uptake of N (310.62 kg $ha^{-1}$) followed by sequence 1 (289.46 kg N $ha^{-1}$). The lowest N uptake by sequence 8 was mainly due to low N content of the crops, having lower yields too. In 2nd year, sequence 10 recorded the highest uptake of N (318.34 kg $ha^{-1}$) which was at par with sequence 2 (315.73 kg N $ha^{-1}$). Similar trend was obtained in 3rd year also. By and large, crops like elephant-foot yam, maize, potato, wheat, etc. recorded higher uptake of nutrient thereby causing higher uptake by the sequences as a whole than others. Large variation was noted in N uptake between sequences 4 and 5 (jute-based sequences) in all the three years of experimentation due to higher uptake by the crops in one than the other (though variation in N uptake in jute crop between the two sequence were less). Bhunia *et al.* (1997) earlier reported alike.

#### 4.4.2.2 Phosphorus uptake by the different systems of cropping

Significant variation was noted in phosphorus uptake by the different systems of cropping in all the three years of experimentation (Table 4.85). Phosphorus uptake showed progressive increase, in most of the sequences tried, over the years of cropping with low variation. Differential uptake of P by the crops in various systems resulted significant variation in P uptake by the systems as a result of cropping, namely, higher P uptake by all the crops in sequence 6 resulted in highest P uptake by the sequence in all the years of experimentation. Phosphorus uptake was lower in

**TABLE 4.85**

**Nitrogen, phosphorus and potassium uptake by different systems of cropping**

| Cropping sequence | N uptake (kg $ha^{-1}$) | | | P uptake (kg $ha^{-1}$) | | | K uptake (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 289.46 | 250.86 | 276.49 | 41.96 | 47.30 | 49.06 | 285.51 | 254.29 | 271.45 |
| 2. E-M-G | 252.83 | 315.73 | 343.41 | 65.25 | 84.83 | 98.71 | 232.77 | 293.91 | 325.59 |
| 3.E-Md-S | 180.63 | 275.57 | 292.70 | 57.52 | 82.41 | 85.06 | 176.69 | 300.98 | 308.21 |
| 4. Jo-G-P-S | 250.71 | 257.99 | 267.71 | 47.42 | 52.51 | 55.30 | 186.87 | 199.21 | 208.51 |
| 5. Jo-Ra-Rb | 168.16 | 169.70 | 196.62 | 73.37 | 63.90 | 77.68 | 176.01 | 183.22 | 189.09 |
| 6. E-W-Gn | 256.35 | 281.17 | 314.04 | 84.11 | 91.92 | 103.88 | 235.32 | 257.45 | 302.90 |
| 7. G-Ra-Md | 151.32 | 208.03 | 213.92 | 30.56 | 44.24 | 43.71 | 145.28 | 198.56 | 215.00 |
| 8. Gm-Ra-Rb | 133.36 | 151.62 | 146.77 | 43.78 | 46.79 | 45.58 | 175.97 | 190.09 | 186.67 |
| 9. M(Gi)-G-P | 310.62 | 271.03 | 316.17 | 48.64 | 47.27 | 52.92 | 287.33 | 264.64 | 288.74 |
| 10. E(Ci)-M-G | 253.26 | 318.34 | 354.52 | 61.70 | 83.97 | 108.36 | 226.46 | 276.20 | 336.67 |
| SEm(±) | 8.39 | 4.19 | 4.18 | 4.25 | 4.27 | 4.52 | 4.02 | 4.20 | 4.19 |
| CD at 5% | 24.91 | 12.44 | 12.40 | 12.62 | 12.69 | 13.42 | 11.93 | 12.47 | 12.44 |

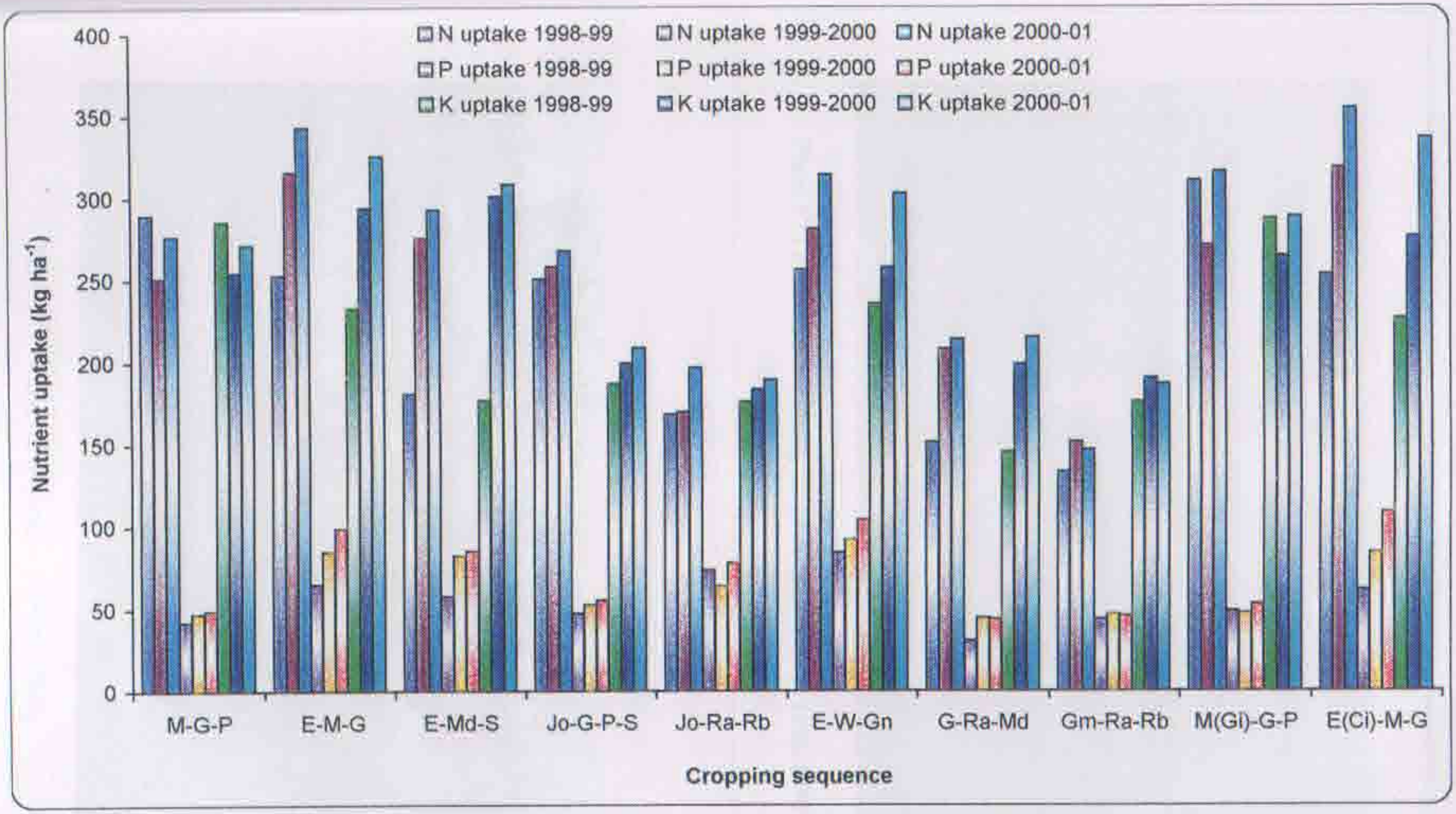



Fig. 14 : Nitrogen, phosphorus and potassium uptake by different systems of cropping

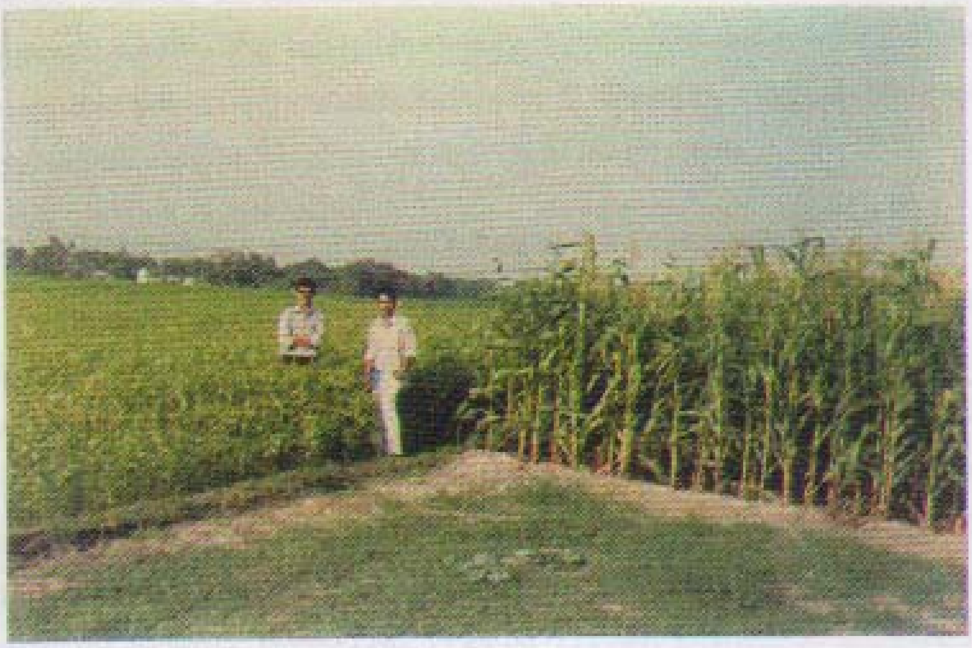


**Plate 17 : Maize at tasselling stage in sequence 2 (1998-1999)**

**Plate 18 : Maize in sequence 1 (1999-2000)**

sequence 1 during all the three years of experimentation which was at par with sequence 8 (Gm-Ra-Rb) and 4 (Jo-G-P-S). Uptake of P was relatively higher with elephant-foot yam thereby signifying higher P uptake by elephant-foot yam-based cropping sequences during all the three years of investigation.

#### 4.4.2.3 Potassium uptake by the different systems of cropping

Potassium uptake by the different systems of cropping exhibited significant variation among themselves in all the three years of experimentation (Table 4.85). Relatively lower K uptake by the sequences was noted in first two years, while it was higher in the 3rd year. Sequences comprising maize and elephant-foot yam showed higher uptake compared with the others. No significant variation in K uptake became evident between the two jute-based sequences (4 and 5). In 1st year, sequence 9 recorded the highest K uptake (287.33 kg $ha^{-1}$) closely followed by sequence 1. In 2nd year, the highest potassium uptake was noted in sequence 3 (300.98 kg $ha^{-1}$) while sequence 5 had the lowest. In 3rd year, sequence 10 recorded the highest uptake (336.67 kg $ha^{-1}$) which was at par with sequence 2.

## 4.5 Soil fertility

### 4.5.1 Total N content (%) in soil

Different cropping sequences had significant effect on final N content of soil at the end of each of the three years of experimentation, as well as on the N content of soils at the end of the investigation. Nitrogen content of soil was improved in unequal proportions over the years in all the cropping sequences except in sequence 2 which resulted decline in soil fertility (Table 4.86, 4.87, 4.88 and 4.89). Improvement of soil fertility under high intensity crop rotations was earlier reported by Verma and Yadav, 1985.

The greatest increase in total N in soil at the end of 3 years of cropping was observed with cropping sequence 4 (Jo-G-P-S), while the lowest improvement was found with cropping sequence 9 [M(Gi)-G-P], *i.e.,* an increase of 214 and 25 kg N $ha^{-1}$, respectively; while cropping sequence 2 recorded a decrease of 18 kg N $ha^{-1}$ at the end.

In first year, the greatest improvement of total N content in soil was seen with cropping sequence 6 (an increase in 45 kg N $ha^{-1}$) followed by sequence 4 and 8, respectively. In the 2nd year, however, cropping sequence 4 recorded the maximum improvement followed by sequence 8 and the same trends were obtained in the 3rd year also.

The increase in total N content was highest after green manure in cropping sequence 8 in the 3rd year while the decrease was maximum after mustard in sequence 3 in the 2nd year. In general, total N content of soil was decreased after maize, rice (*aman*) and mustard while other crops showed improvement (Fig. 15).

### 4.5.2 Available phosphorus (P) content (kg $ha^{-1}$) in soil

The available phosphorus content of soils was increased after completion of each cropping sequence in all the three years of experimentation (Table 4.90, 4.91, 4.92 and 4.93). After the completion of 3 years of cropping, the final values of available phosphorus content of soil was increased to a greater proportion than normal, though not uniform, in different cropping sequences which might be due to the fact that arsenic might had interacted with soil phosphorus leading to replacement of phosphate by arsenate (as the chemistry and behaviour of P and As in soil were similar). The above fact was earlier reported by Mok and Wai (1994).

The available phosphorus content of soils in different cropping sequences were higher than the initial value at the end of 3rd year and it varied from 39.9 to 33.7kg $ha^{-1}$ in sequences 4 and 7 which were the highest and lowest values, respectively, as against the initial value of 29.7 kg $ha^{-1}$ (Table 4.93).

In 1st year, cropping sequence 1 had the greatest increase (6.0 kg $ha^{-1}$ over initial value) while sequence 8 had the minimum increase (0.7 kg $ha^{-1}$) in available phosphorus content of soil. In 2nd year, cropping sequence 5 had the maximum increase while it was in sequences 5 and 8 in the final year of cropping. The change in phosphorus values were more in *rabi* and in pre-*kharif* or in summer crops suggesting greater arsenic mobilization and transformation during those months. Maize, mustard, wheat, *boro* rice, etc. decreased soil available phosphorus content; while elephant-foot yam, jute, groundnut, sesame, potato, etc. increased it. Both *aman* and *boro* rices

## TABLE 4.86

**Effect of different systems of cropping on total nitrogen content of soil in 1998-1999**

| Cropping sequence | N content of soil (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 1420 | 1375 | 1420 | 1442 | |
| 2. E-M-G | 1420 | 1434 | 1376 | 1400 | |
| 3. E-Md-S | 1420 | 1435 | 1416 | 1446 | |
| 4. Jo-G-P-S | 1420 | 1432 | 1450 | 1460 | 1464 |
| 5. Jo-Ra-Rb | 1420 | 1448 | 1422 | 1456 | |
| 6. E-W-Gn | 1420 | 1437 | 1450 | 1465 | |
| 7. G-Ra-Md | 1420 | 1450 | 1415 | 1430 | |
| 8. Gm-Ra-Rb | 1420 | 1484 | 1426 | 1455 | |
| 9. M(Gi)-G-P | 1420 | 1396 | 1415 | 1437 | |
| 10. E(Ci)-M-G | 1420 | 1444 | 1410 | 1436 | |

## TABLE 4.87

**Effect of different systems of cropping on total nitrogen content of soil in 1999-2000**

| Cropping sequence | N content of soil (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 1442 | 1380 | 1416 | 1465 | |
| 2. E-M-G | 1400 | 1430 | 1368 | 1420 | |
| 3. E-Md-S | 1446 | 1456 | 1420 | 1464 | |
| 4. Jo-G-P-S | 1464 | 1490 | 1510 | 1540 | 1564 |
| 5. Jo-Ra-Rb | 1456 | 1482 | 1440 | 1475 | |
| 6. E-W-Gn | 1465 | 1478 | 1480 | 1500 | |
| 7. G-Ra-Md | 1430 | 1448 | 1472 | 1436 | |
| 8. Gm-Ra-Rb | 1455 | 1520 | 1480 | 1507 | |
| 9. M(Gi)-G-P | 1437 | 1372 | 1394 | 1412 | |
| 10. E(Ci)-M-G | 1436 | 1450 | 1406 | 1436 | |

## TABLE 4.88

**Effect of different systems of cropping on total nitrogen content of soil in 2000-2001**

| Cropping sequence | N content of soil (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 1465 | 1410 | 1430 | 1474 | |
| 2. E-M-G | 1420 | 1430 | 1370 | 1402 | |
| 3. E-Md-S | 1464 | 1482 | 1467 | 1480 | |
| 4. Jo-G-P-S | 1564 | 1578 | 1600 | 1620 | 1634 |
| 5. Jo-Ra-Rb | 1475 | 1488 | 1462 | 1500 | |
| 6. E-W-Gn | 1500 | 1510 | 1518 | 1538 | |
| 7. G-Ra-Md | 1436 | 1474 | 1500 | 1478 | |
| 8. Gm-Ra-Rb | 1507 | 1554 | 1522 | 1546 | |
| 9. M(Gi)-G-P | 1412 | 1400 | 1426 | 1445 | |
| 10. E(Ci)-M-G | 1436 | 1460 | 1412 | 1442 | |

## TABLE 4.89

**Effect of different systems of cropping on total nitrogen content of soil**

| Cropping sequence | N content of soil (kg $ha^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | | 1999-2000 | | 2000-2001 | |
| | Initial | Final | Initial | Final | Initial | Final |
| 1. M-G-P | 1420 | 1442 | 1442 | 1465 | 1465 | 1474 |
| 2. E-M-G | 1420 | 1400 | 1400 | 1420 | 1420 | 1402 |
| 3. E-Md-S | 1420 | 1446 | 1446 | 1464 | 1464 | 1480 |
| 4. Jo-G-P-S | 1420 | 1464 | 1464 | 1564 | 1564 | 1634 |
| 5. Jo-Ra-Rb | 1420 | 1456 | 1456 | 1475 | 1475 | 1500 |
| 6. E-W-Gn | 1420 | 1465 | 1465 | 1500 | 1500 | 1538 |
| 7. G-Ra-Md | 1420 | 1430 | 1430 | 1436 | 1436 | 1478 |
| 8. Gm-Ra-Rb | 1420 | 1455 | 1455 | 1507 | 1507 | 1540 |
| 9. M(Gi)-G-P | 1420 | 1437 | 1437 | 1412 | 1412 | 1445 |
| 10. E(Ci)-M-G | 1420 | 1436 | 1436 | 1436 | 1436 | 1442 |
| SEm (±) | | 9.51 | | 7.19 | | 17.78 |
| CD at 5% | | 28.24 | | 21.35 | | 52.80 |

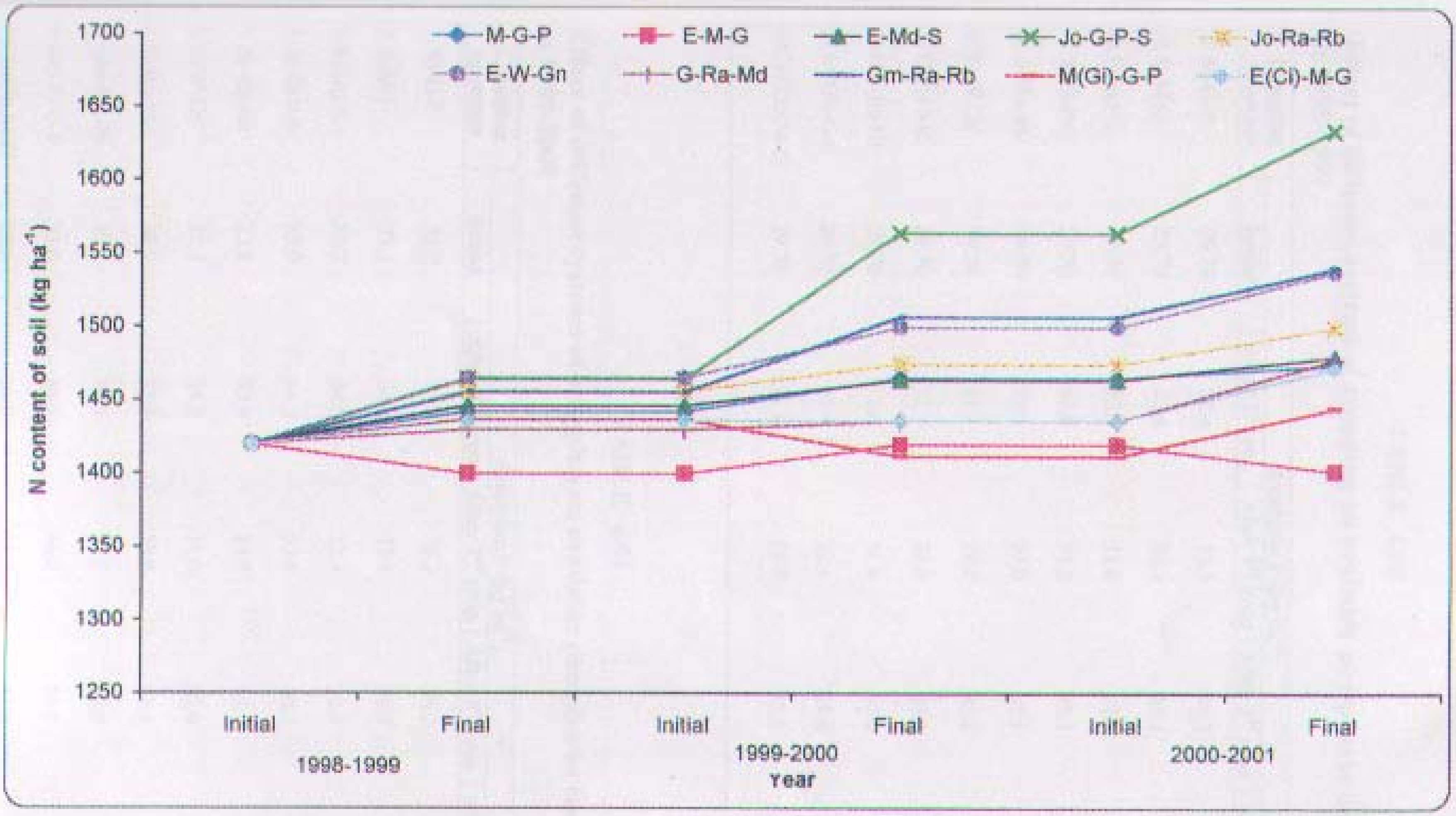



Fig. 15 : Variation in N content of soil (kg $ha^{-1}$) with different systems of cropping

## TABLE 4.90

**Effect of different systems of cropping on available phosphorus content of soil in 1998-1999**

| Cropping sequence | Available P (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 29.70 | 28.4 | 33.1 | 35.7 | |
| 2. E-M-G | 29.70 | 32.6 | 30.3 | 35.1 | |
| 3. E-Md-S | 29.70 | 32.8 | 31.6 | 33.7 | |
| 4. Jo-G-P-S | 29.70 | 30.9 | 32.2 | 33.1 | 33.9 |
| 5. Jo-Ra-Rb | 29.70 | 30.1 | 31.0 | 32.1 | |
| 6. E-W-Gn | 29.70 | 31.1 | 29.4 | 32.4 | |
| 7. G-Ra-Md | 29.70 | 31.7 | 32.6 | 30.8 | |
| 8. Gm-Ra-Rb | 29.70 | 31.4 | 31.8 | 30.4 | |
| 9. M(Gi)-G-P | 29.70 | 30.4 | 32.4 | 33.6 | |
| 10. E(Ci)-M-G | 29.70 | 31.9 | 28.7 | 32.8 | |

## TABLE 4.91

**Effect of different systems of cropping on available phosphorus content of soil in 1999-2000**

| Cropping sequence | Available P (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 35.7 | 31.2 | 33.2 | 36.2 | |
| 2. E-M-G | 35.1 | 36.8 | 33.1 | 35.7 | |
| 3. E-Md-S | 33.7 | 34.9 | 32.4 | 33.6 | |
| 4. Jo-G-P-S | 33.9 | 34.5 | 35.6 | 36.7 | 37.1 |
| 5. Jo-Ra-Rb | 32.1 | 32.9 | 33.9 | 35.2 | |
| 6. E-W-Gn | 32.4 | 34.2 | 31.0 | 32.6 | |
| 7. G-Ra-Md | 30.8 | 32.6 | 33.8 | 31.4 | |
| 8. Gm-Ra-Rb | 30.4 | 32.5 | 33.7 | 34.9 | |
| 9. M(Gi)-G-P | 33.6 | 34.9 | 36.2 | 36.3 | |
| 10. E(Ci)-M-G | 32.8 | 35.2 | 31.0 | 33.0 | |

## TABLE 4.92

**Effect of different systems of cropping on available phosphorus content of soil in 2000-2001**

| Cropping sequence | Available P (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1$^{st}$ crop | After 2$^{nd}$ crop | After 3$^{rd}$ crop | After 4$^{th}$ crop |
| 1. M-G-P | 36.2 | 33.8 | 36.4 | 38.9 | |
| 2. E-M-G | 35.7 | 36.9 | 34.4 | 35.9 | |
| 3. E-Md-S | 33.6 | 35.7 | 34.2 | 35.4 | |
| 4. Jo-G-P-S | 37.1 | 38.7 | 39.0 | 39.6 | 39.9 |
| 5. Jo-Ra-Rb | 35.2 | 36.4 | 37.9 | 39.8 | |
| 6. E-W-Gn | 32.6 | 34.4 | 33.0 | 34.8 | |
| 7. G-Ra-Md | 31.4 | 33.8 | 35.2 | 33.7 | |
| 8. Gm-Ra-Rb | 34.9 | 37.3 | 38.2 | 39.5 | |
| 9. M(Gi)-G-P | 36.3 | 37.9 | 39.3 | 39.4 | |
| 10. E(Ci)-M-G | 33.0 | 35.4 | 34.0 | 36.4 | |

## TABLE 4.93

**Effect of different systems of cropping on available phosphorus content of soil**

| Cropping sequence | Available P (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | | 1999-2000 | | 2000-2001 | |
| | Initial | Final | Initial | Final | Initial | Final |
| 1. M-G-P | 29.70 | 35.7 | 35.7 | 36.2 | 36.2 | 38.9 |
| 2. E-M-G | 29.70 | 35.1 | 35.1 | 35.7 | 35.7 | 35.9 |
| 3. E-Md-S | 29.70 | 33.7 | 33.7 | 33.6 | 33.6 | 35.4 |
| 4. Jo-G-P-S | 29.70 | 33.9 | 33.9 | 37.1 | 37.1 | 39.9 |
| 5. Jo-Ra-Rb | 29.70 | 32.1 | 32.1 | 35.2 | 35.2 | 39.8 |
| 6. E-W-Gn | 29.70 | 32.4 | 32.4 | 32.6 | 32.6 | 34.8 |
| 7. G-Ra-Md | 29.70 | 30.8 | 30.8 | 31.4 | 31.4 | 33.7 |
| 8. Gm-Ra-Rb | 29.70 | 30.4 | 30.4 | 34.9 | 34.9 | 39.5 |
| 9. M(Gi)-G-P | 29.70 | 33.6 | 33.6 | 36.3 | 36.3 | 39.4 |
| 10. E(Ci)-M-G | 29.70 | 32.8 | 32.8 | 33.0 | 33.0 | 36.4 |
| SEm (±) | | 0.44 | | 0.59 | | 0.57 |
| CD at 5% | | 1.31 | | 1.75 | | 1.69 |

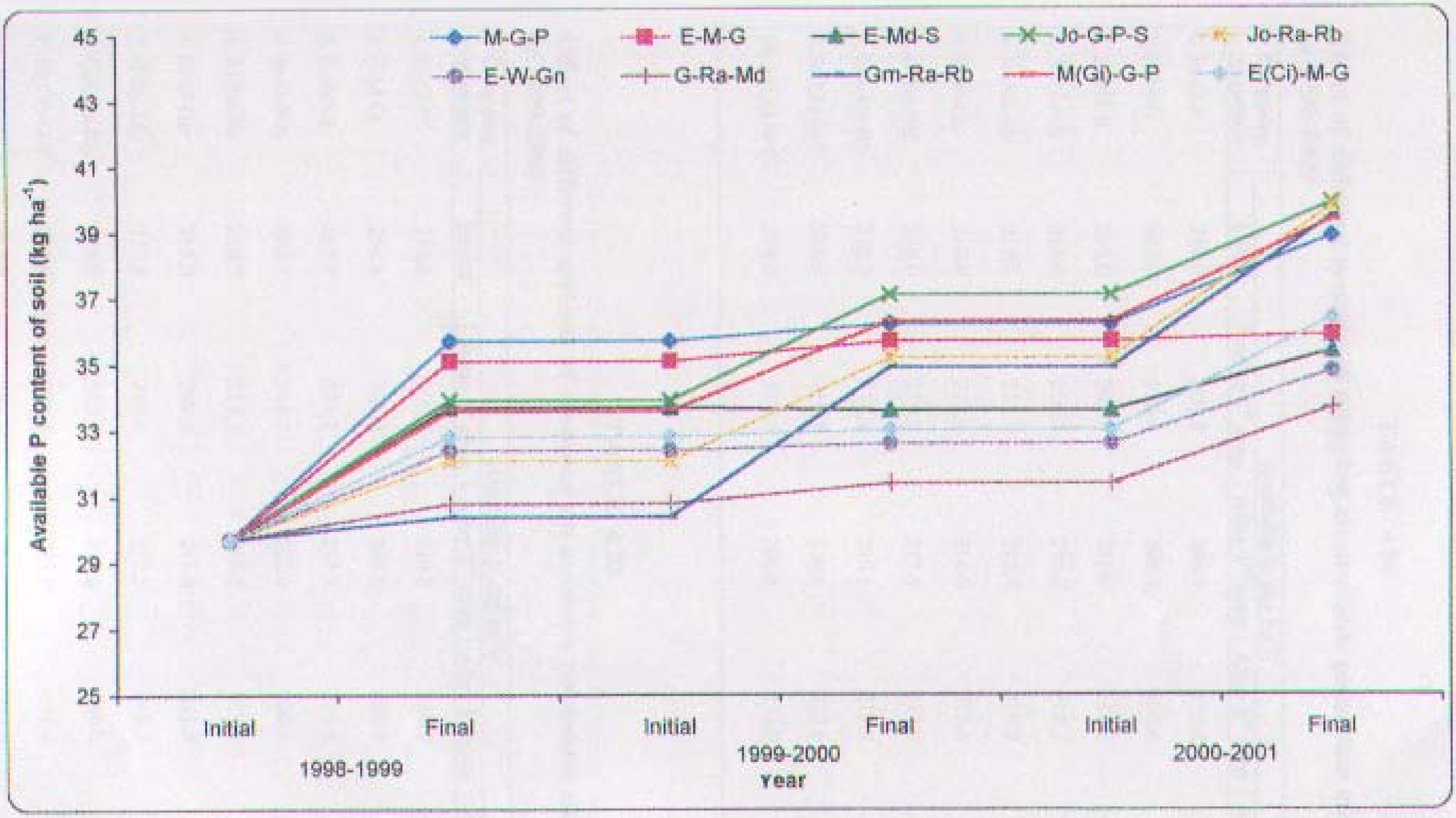



Fig. 16 : Variation in available P content of soil (kg $ha^{-1}$) with different systems of cropping

## TABLE 4.94

**Effect of different systems of cropping on available potassium content of soil in 1998-1999**

| Cropping sequence | Available K (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 218.0 | 206.3 | 209.7 | 215.8 | |
| 2. E-M-G | 218.0 | 210.4 | 199.7 | 204.8 | |
| 3. E-Md-S | 218.0 | 208.9 | 211.0 | 217.2 | |
| 4. Jo-G-P-S | 218.0 | 216.4 | 219.6 | 219.1 | 220.3 |
| 5. Jo-Ra-Rb | 218.0 | 215.7 | 215.4 | 219.7 | |
| 6. E-W-Gn | 218.0 | 212.6 | 214.0 | 213.6 | |
| 7. G-Ra-Md | 218.0 | 219.2 | 217.6 | 217.9 | |
| 8. Gm-Ra-Rb | 218.0 | 217.4 | 216.1 | 219.2 | |
| 9. M(Gi)-G-P | 218.0 | 219.7 | 220.4 | 222.6 | |
| 10. E(Ci)-M-G | 218.0 | 213.4 | 206.4 | 212.0 | |

## TABLE 4.95

**Effect of different systems of cropping on available potassium content of soil in 1999-2000**

| Cropping sequence | Available K (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 215.8 | 205.7 | 210.2 | 214.9 | |
| 2. E-M-G | 204.8 | 203.4 | 203.0 | 208.9 | |
| 3. E-Md-S | 217.2 | 211.2 | 213.5 | 218.4 | |
| 4. Jo-G-P-S | 220.3 | 218.3 | 221.0 | 220.1 | 222.5 |
| 5. Jo-Ra-Rb | 219.7 | 217.1 | 216.2 | 219.1 | |
| 6. E-W-Gn | 213.6 | 208.2 | 211.6 | 211.0 | |
| 7. G-Ra-Md | 217.9 | 219.0 | 217.2 | 218.2 | |
| 8. Gm-Ra-Rb | 219.2 | 217.2 | 215.8 | 219.0 | |
| 9. M(Gi)-G-P | 222.6 | 216.1 | 217.7 | 218.8 | |
| 10. E(Ci)-M-G | 212.0 | 211.2 | 209.0 | 215.7 | |

## TABLE 4.96

**Effect of different systems of cropping on available potassium content of soil in 2000-2001**

| Cropping sequence | Available K (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 214.9 | 209.0 | 213.4 | 218.4 | |
| 2. E-M-G | 208.9 | 207.2 | 206.0 | 212.6 | |
| 3. E-Md-S | 218.4 | 210.1 | 212.0 | 218.3 | |
| 4. Jo-G-P-S | 222.5 | 223.6 | 225.3 | 228.0 | 229.3 |
| 5. Jo-Ra-Rb | 219.1 | 216.0 | 214.1 | 218.6 | |
| 6. E-W-Gn | 211.0 | 210.1 | 213.6 | 212.9 | |
| 7. G-Ra-Md | 218.2 | 220.3 | 218.7 | 219.2 | |
| 8. Gm-Ra-Rb | 219.0 | 218.8 | 217.6 | 219.9 | |
| 9. M(Gi)-G-P | 218.8 | 220.1 | 221.4 | 223.1 | |
| 10. E(Ci)-M-G | 215.7 | 213.9 | 210.0 | 217.6 | |

## TABLE 4.97

**Effect of different systems of cropping on available potassium content of soil**

| Cropping sequence | Available K (kg $ha^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | | 1999-2000 | | 2000-2001 | |
| | Initial | Final | Initial | Final | Initial | Final |
| 1. M-G-P | 218.0 | 215.8 | 215.8 | 214.9 | 214.9 | 218.4 |
| 2. E-M-G | 218.0 | 204.8 | 204.8 | 208.9 | 208.9 | 212.6 |
| 3. E-Md-S | 218.0 | 217.2 | 217.2 | 218.4 | 218.4 | 218.3 |
| 4. Jo-G-P-S | 218.0 | 220.3 | 220.3 | 222.5 | 222.5 | 229.3 |
| 5. Jo-Ra-Rb | 218.0 | 219.9 | 219.9 | 219.1 | 219.1 | 218.6 |
| 6. E-W-Gn | 218.0 | 213.6 | 213.6 | 211.0 | 211.0 | 212.9 |
| 7. G-Ra-Md | 218.0 | 217.9 | 217.9 | 218.2 | 218.2 | 219.2 |
| 8. Gm-Ra-Rb | 218.0 | 219.2 | 219.2 | 219.0 | 219.0 | 219.9 |
| 9. M(Gi)-G-P | 218.0 | 222.6 | 222.6 | 218.8 | 218.8 | 223.1 |
| 10. E(Ci)-M-G | 218.0 | 212.0 | 212.0 | 215.7 | 215.7 | 217.6 |
| SEm (±) | | 0.98 | | 2.09 | | 1.83 |
| CD at 5% | | 2.91 | | 6.20 | | 5.43 |

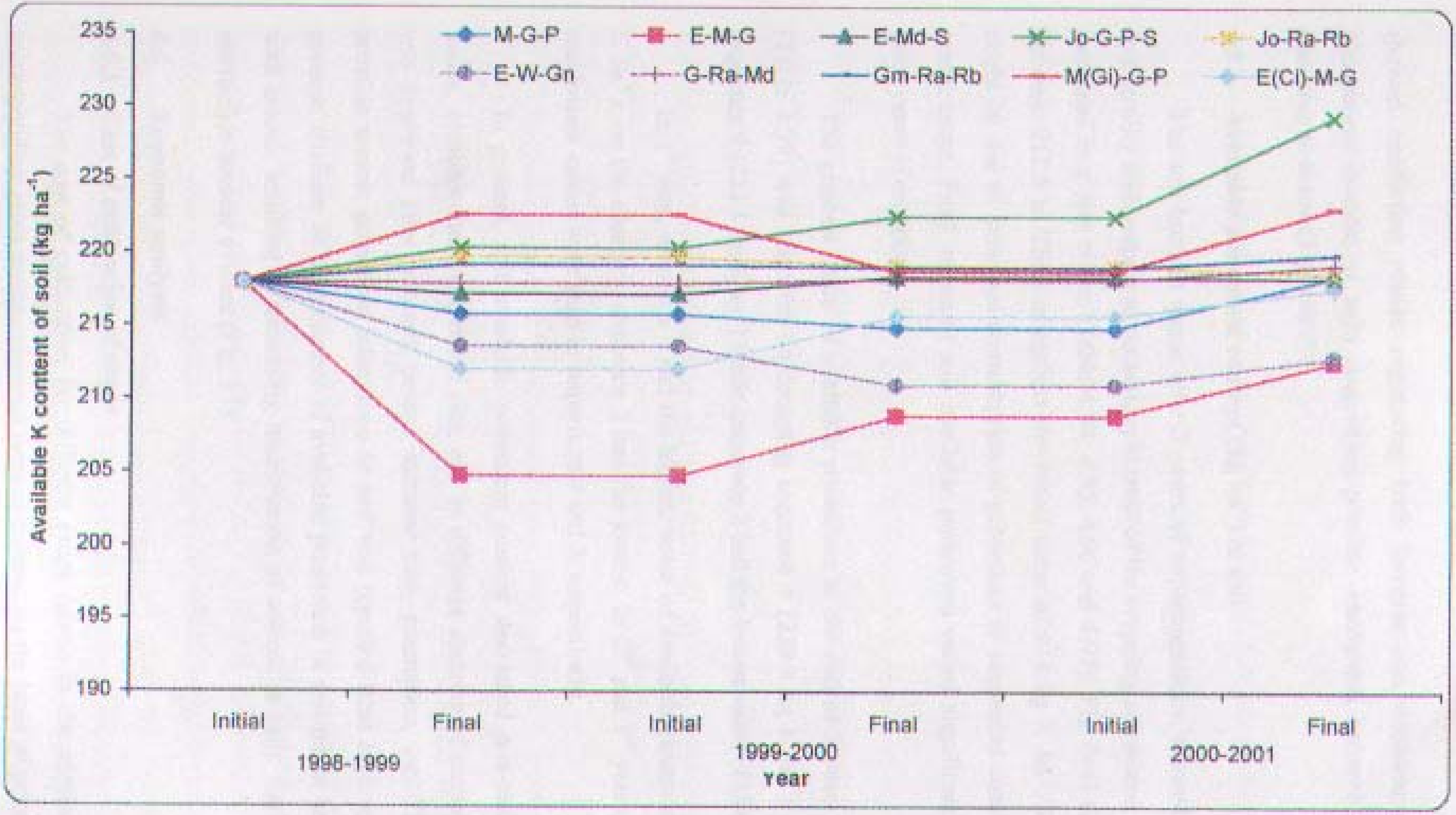



**Fig. 17 : Variation in available K content of soil (kg ha$^{-1}$) with different systems of cropping**

showed conflicting results registering both increase and decrease in available phosphorus content of soils suggesting possible interaction between arsenic and phosphorus in soil (Fig. 16).

### 4.5.3 Available potassium content (kg $ha^{-1}$) in soil

The soil nutrient status after 3 years of experimentation showed decrease in soil fertility with respect to potassium in most of the cropping sequences; while it had increased in a few others (Table 4.94, 4.95, 4.96 and 4.97). The final values ranged between 212.6 to 229.3 as against the initial value of 218 kg K $ha^{-1}$. The decrease might be due to luxurious consumption of potassium in sequences consisting of the cereal crops. Final values of soil available potassium varied significantly in all the three years of cropping.

The greatest value of available potassium at the end of 3 years of cropping (Table 4.97) was observed on cropping sequence 4 (229.3 kg K $ha^{-1}$) followed by sequence 9 (223.1 kg K $ha^{-1}$) while sequence 2 had the lowest value (212.6 kg K $ha^{-1}$).

In 1st year, sequence 9 had the highest value of available potassium (222.6 kg K $ha^{-1}$); on the contrary, sequence 2 had the lowest. In 2nd and 3rd years, the highest and lowest values were seen in sequences 4 and 2, respectively.

In general, soil available potassium content decreased non-uniformly after maize, elephant-foot yam, *aman* rice, etc. in different systems of cropping, while it was improved after mustard, potato, summer rice, greengram, etc. Though some possible arsenic potassium interaction in soil was reported (that high application of potassic fertilizer or high content of available potassium in soil might had interacted with arsenic resulting in increasing mobilisation of arsenic in soil). Earlier, no such interaction became evident (Fig. 17).

## 4.6 Economic analyses

### 4.6.1 Cost of cultivation of crops

The cost of cultivation for different crops (given in the appendix) and the corresponding gross returns obtained were calculated on the basis of prices of various items and produces prevalent in the locality. The highest cost of cultivation was seen in elephant-foot yam owing to high cost incurred in procuring good planting material. This was followed by potato. Cost of cultivation was slightly higher in summer rice than in winter rice (Table 4.98).

### 4.6.2 Gross and net returns incurred from different systems of cropping

Results showed variation in gross returns obtained from different systems of cropping in all the three years of experimentation. In 1st year, sequence 6 (E-W-Gn) recorded the highest gross return (Rs 1,38,770 $ha^{-1}$) followed by sequence 10 (Rs 89,300) while the lowest gross return was obtained in sequence 7 (G-Ra-Md) (Table 4.99; Fig. 18).

In 2nd year, sequence 3 (E-Md-S) recorded the highest gross return (Rs1,41,740 $ha^{-1}$) followed by sequence 6 (E-W-Gn) (Rs1,31,570 $ha^{-1}$). Sequence 2, 6 and 10 recorded comparatively higher gross returns. The sequence 7 (G-Ra-Md) recorded the lowest gross return.

In 3rd year, the highest gross return (Rs1,49,900 $ha^{-1}$) was obtained in sequence 6 (E-W-Gn) followed by sequence 3 (E-Md-S) which showed no significant variation between themselves. Gross returns were comparatively higher and more or less same in sequences 2 and 10.

Different elephant-foot yam-based sequences (2, 3, 6 and 10) recorded higher gross returns in all the three years of experimentation followed by jute-based sequences (4 and 5). Gross return was comparatively lower in sequence 8 (Gm-Ra-Rb) during all the years of investigation.

Different systems of cropping resulted significant variation in net returns during all the three years of cropping (Table 4.99; Fig. 19). Sequence 6 (E-W-Gn) brought in the highest net return (Rs 67,706 $ha^{-1}$) in 1st year followed by sequences 9 and 5 which were at par. Sequence 3 (E-Md-S) recorded the highest net return during both 2nd and 3rd year of investigation. Variation in net return was obtained in all the three years of investigation between two jute-based sequences. Sequences having both winter and summer rices, *viz,* 5 and 8 differed significantly in net returns during 1st and 3rd year while little variation was noted in 2nd year. So, it was evident that most of the sequences resulted in higher net returns compared with sequence 8 (Gm-Ra-Rb).

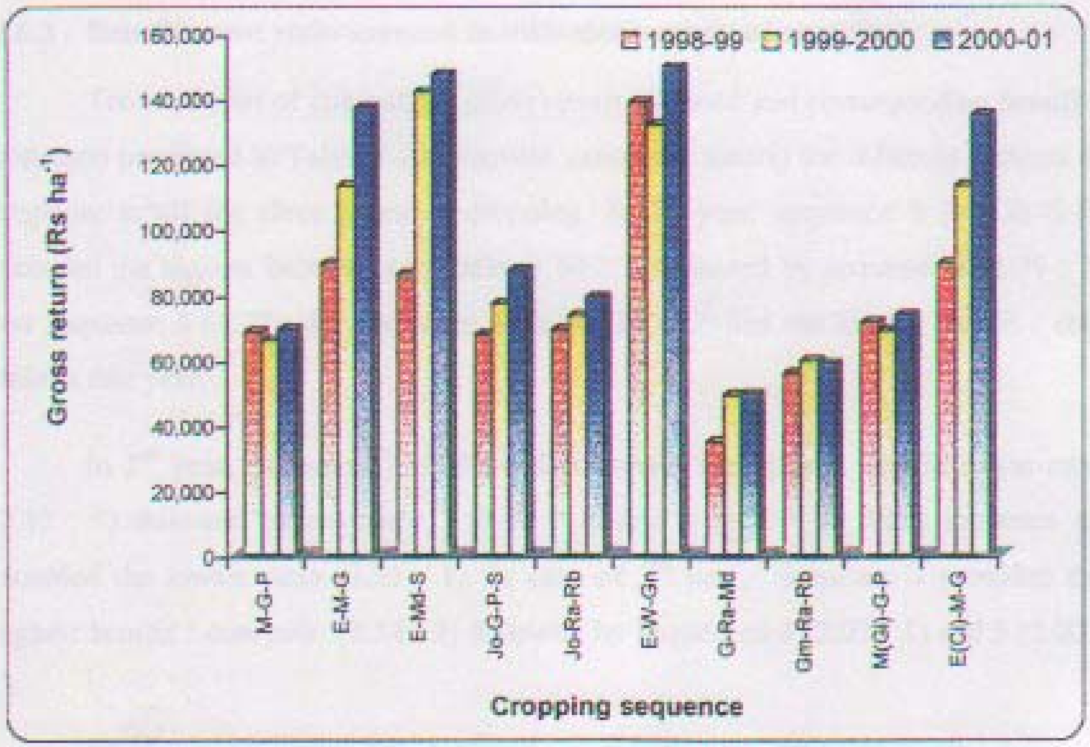



**Fig. 18 : Gross return (Rs ha$^{-1}$) in different systems of cropping**

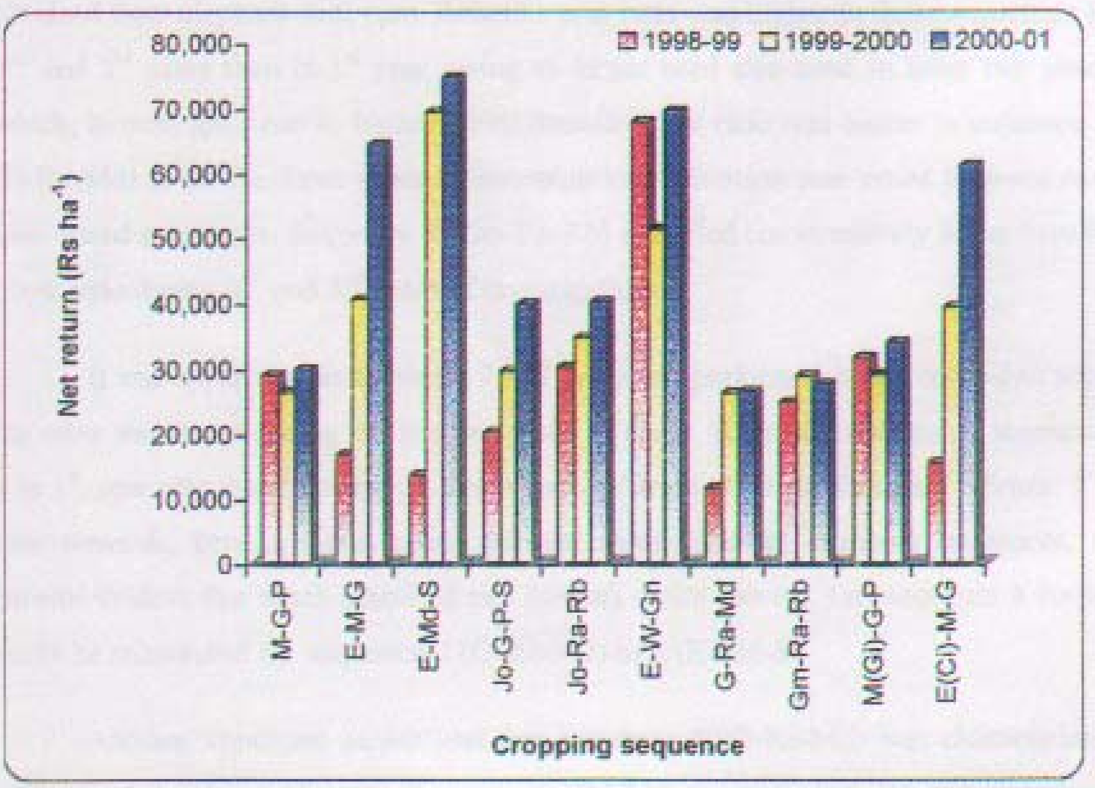



**Fig. 19 : Net return (Rs ha$^{-1}$) in different systems of cropping**

### 4.6.3 Benefit : cost ratio accrued in different systems of cropping

The total cost of cultivation, gross return obtained and corresponding benefit : cost ratio presented in Table 4.100 showed variations among the different systems of cropping in all the three years of cropping. In 1st year, sequence 9 [M(Gi)-G-P] recorded the highest benefit : cost ratio (1.80 : 1) followed by sequence 8 (1.79 : 1) and sequence 5 (1.77 : 1). Sequence 3 (E-Md-S) recorded the lowest benefit : cost ratio in that year.

In 2nd year, sequence 7 (G-Ra-Md) recorded the highest benefit : cost ratio (2.13 : 1) followed by sequence 3 (1.95 : 1) and 8 (1.92 : 1) while sequence 10 recorded the lowest ratio (1.53 : 1). In case of 3rd year, sequence 7 provided the highest benefit : cost ratio (2.14 : 1) followed by sequences 3 (2.03 : 1) and 5 (2.02 : 1).

Benefit : cost ratios obtained in different systems of cropping having elephant-foot yam were relatively higher compared with the others owing to higher return obtained from elephant-foot yam. Benefit : cost ratio was higher in those sequences in 2nd and 3rd years than in 1st year owing to larger seed size used in latter two years which, in turn, gave rise to higher yield. Benefit : cost ratio was higher in sequence 7 (G-Ra-Md) in all the three years of investigation. Variation was noted between two jute- based sequences. Sequence 8 (Gm-Ra-Rb) recorded comparatively lower benefit : cost ratio during 2nd and 3rd years of investigation.

It was apparent that sequence 3 and 7, by far, performed better compared with the other sequences during the last two years of study. Poor performance of sequence 3 in 1st year was due primarily to lower income from elephant-foot yam . From 2nd year onwards, benefit : cost ratios accrued from different cropping sequences, it became evident that much practised rice (*aman*) – rice (*boro*), *i.e.,* sequence 8 could easily be substituted by sequence 7 (G-Ra-Md) or 3 (E-Md-S).

Another important aspect was that sequence 7 (G-Ra-Md) was characterised by the lowest volume of water requirement (0.12 ha m year$^{-1}$) but the corresponding benefit : cost ratio was higher when compared with the volume of water given to other sequences (Table 3.3) through irrigation *vis-à-vis* their corresponding benefit : cost

## TABLE 4.98

### Cost of cultivation of different crops

| Crop | | Cost of cultivation (Rs $ha^{-1}$) |
|---|---|---|
| Elephant-foot yam | | 58,780 |
| Maize | | 11,034 |
| Cowpea | | 1,050 |
| Greengram | | 2,788 |
| Mustard | | 7,123 |
| Jute | | 12,327 |
| Rice | ➢ Winter (*aman*) | 13,140 |
| | ➢ Summer (*boro*) | 13,544 |
| Groundnut | | 12,284 |
| Potato | | 25,806 |
| Sesame | | 6,684 |
| Wheat | | 9,478 |
| Green manure | | 4,480 |

## TABLE 4.99

### Gross return and net return obtained from different systems of cropping

| Cropping sequence | Gross return (Rs $ha^{-1}$) | | | Net return (Rs $ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 68,440 | 65,910 | 69,300 | 28,812 | 26,282 | 29,672 |
| 2. E-M-G | 89,200 | 1,13,000 | 1,36,850 | 16,598 | 40,398 | 64,248 |
| 3. E-Md-S | 86,040 | 1,41,740 | 1,47,060 | 13,453 | 69,153 | 74,473 |
| 4. Jo-G-P-S | 67,610 | 77,060 | 87,250 | 20,005 | 29,455 | 39,645 |
| 5. Jo-Ra-Rb | 69,100 | 73,500 | 79,000 | 30,089 | 34,489 | 39,989 |
| 6. E-W-Gn | 1,38,770 | 1,31,570 | 1,49,900 | 67,706 | 51,148 | 69,478 |
| 7. G-Ra-Md | 34,600 | 49,280 | 49,490 | 11,549 | 26,229 | 26,439 |
| 8. Gm-Ra-Rb | 55,930 | 59,920 | 58,800 | 24,766 | 28,756 | 27,636 |
| 9. M(Gi)-G-P | 71,460 | 68,810 | 73,700 | 31,622 | 28,982 | 33,872 |
| 10. E(Ci)-M-G | 89,300 | 1,13,000 | 1,34,760 | 15,348 | 39,148 | 60,908 |
| SEm (±) | 2066.9 | 2064.3 | 4194.8 | 1473.92 | 2158.2 | 2031.9 |
| CD at 5% | 6141.3 | 6133.5 | 12462.7 | 4379.4 | 6412.5 | 6037.3 |

## TABLE 4.100

**Benefit : cost ratio accrued from different systems of cropping**

| Cropping sequence | Total cost of cultivation $ha^{-1}$ (Rs) | 1998-1999 | | 1999-2000 | | 2000-2001 | |
|---|---|---|---|---|---|---|---|
| | | Gross return $ha^{-1}$ (Rs) | Benefit : cost ratio | Gross return $ha^{-1}$ (Rs) | Benefit : cost ratio | Gross return $ha^{-1}$ (Rs) | Benefit : cost ratio |
| 1. M-G-P | 39,628 | 68,440 | 1.72 : 1 | 65,910 | 1.66 : 1 | 69,300 | 1.74 : 1 |
| 2. E-M-G | 72,602 | 89,200 | 1.22 : 1 | 1,13,000 | 1.55 : 1 | 1,36,850 | 1.88 : 1 |
| 3. E-Md-S | 72,587 | 86,040 | 1.19 : 1 | 1,41,740 | 1.95 : 1 | 1,47,060 | 2.03 : 1 |
| 4. Jo-G-P-S | 47,605 | 67,610 | 1.42 : 1 | 77,060 | 1.61 : 1 | 87,250 | 1.83 : 1 |
| 5. Jo-Ra-Rb | 39,011 | 69,100 | 1.77 : 1 | 73,500 | 1.88 : 1 | 79,000 | 2.02 : 1 |
| 6. E-W-Gn | 80,542 | 1,38,770 | 1.72 : 1 | 1,31,570 | 1.63 : 1 | 1,49,900 | 1.86 : 1 |
| 7. G-Ra-Md | 23,051 | 34,600 | 1.50 : 1 | 49,280 | 2.13 : 1 | 49,490 | 2.14 : 1 |
| 8. Gm-Ra-Rb | 31,164 | 55,930 | 1.79 : 1 | 59,920 | 1.92 : 1 | 58,800 | 1.88 : 1 |
| 9. M(Gi)-G-P | 39,828 | 71,460 | 1.80 : 1 | 68,810 | 1.72 : 1 | 73,700 | 1.85 : 1 |
| 10. E(Ci)-M-G | 73,852 | 89,300 | 1.20 : 1 | 1,13,000 | 1.53 : 1 | 1,34,760 | 1.82 : 1 |

ratio. The same was also true for sequence 3. In case of sequence 8 (Gm-Ra-Rb), although the benefit : cost ratio was higher, yet the volume of water required was also the highest.

## 4.7 Arsenic in soil -plant system

### 4.7.1 Arsenic content in different plant parts of the crops grown in different sequences

Content of As in different plant parts of the crops at 30 days before harvest (DBH), 15 DBH and at harvest covering three years of experimentation have been depicted in Tables 4.101, 4.102 and 4.103 for 1$^{st}$ year; 4.104, 4.105 and 4.106 for 2$^{nd}$ year and 4.107, 4.108 and 4.109 for 3$^{rd}$ year. By and large, the general uptake pattern followed the order of root > stem > leaf > economic produce for most of the crops tried. Similar trend of uptake pattern was earlier reported by Anastasia and Kender (1973).

Arsenic content in various plant parts of crops showed gradual increase in values, the lowest being at 30 DBH which reached the maximum at harvest though some exceptions were also noted. In other words, crops showed gradually increasing arsenic build-up in different plant parts as the growth progressed. The highest arsenic concentration to the extent of 14.00 mg kg$^{-1}$, and the lowest of 0.40 mg kg$^{-1}$ in wheat root and sesame seeds, respectively, were noted at harvest in 2000-2001 and at 30 DBH in 1998-1999.

Various types of crops showed specificity in arsenic build-up in different plant parts. For instance, cereals showed higher build-up than oilseeds, *i.e.,* arsenic tolerance by crops showed variation. Similar observation on arsenic build-up was earlier reported by Adriano (1986).

Among the cereal crops tried, summer rice showed very high values of arsenic contents in various plant parts during all the three years of experimentation. Summer rice grain (dehusked) recorded the maximum uptake (10.00 mg kg$^{-1}$) of arsenic during both 1999-2000 and 2000-2001, at harvest. Different plant parts of summer rice exhibited higher values of arsenic uptake as compared to the corresponding *aman* rice during all the three years of experimentation. Wheat grain recorded lower values of

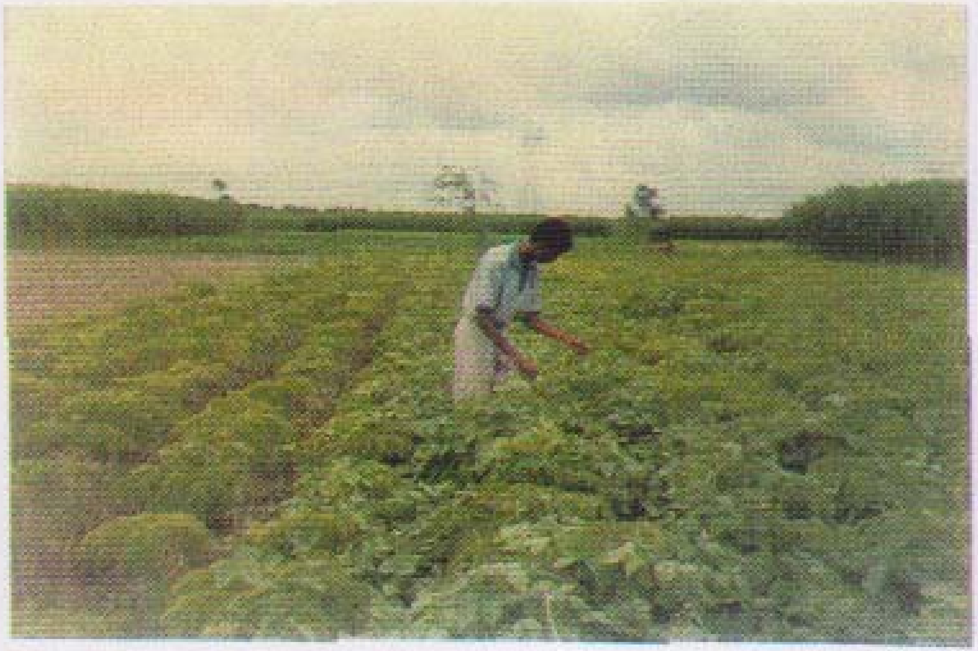


Plate 19 : Elephant-foot yam with cowpea as intercrop in sequence 10 (2000-2001)

Plate 20 : Elephant-foot yam in sequence 3 (2000-2001)

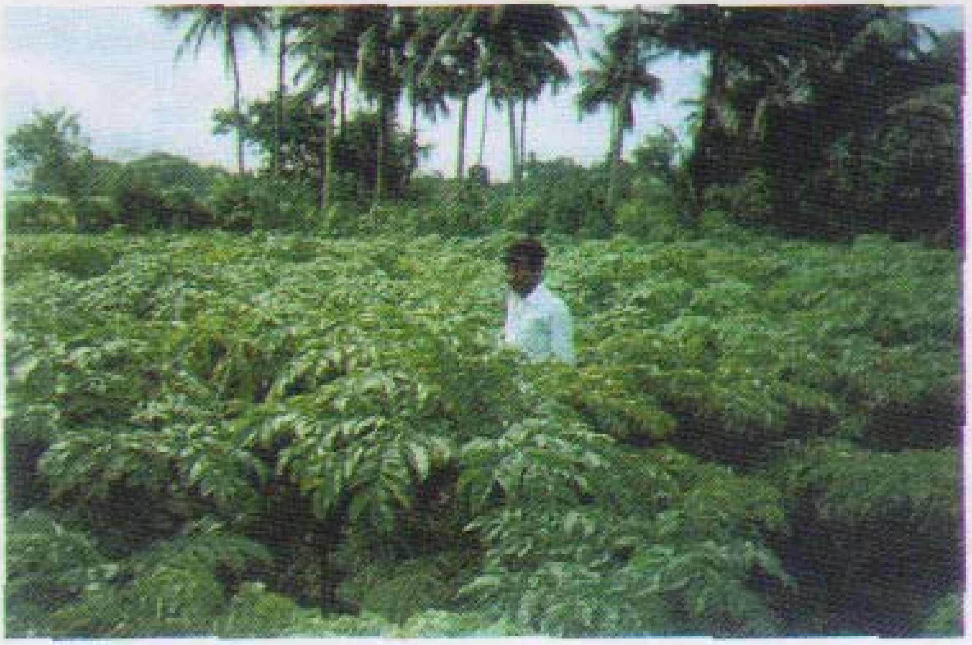


**Plate 21 : Elephant-foot yam in sequence 6 (1998-1999)**

**Plate 22 : Elephant-foot yam in sequence *3 (100 days old crop)***

arsenic uptake than rice. Elephant-foot yam showed moderate values of arsenic content in various plant parts; the highest (4.85 mg $kg^{-1}$) was in economic produce at harvest in 1998-1999 in cropping sequence 2.

Oilseed crops, *viz,* mustard, groundnut and sesame showed lower values of arsenic content in the economic/consumable portions as compared to the cereals.

Roots recorded high values of arsenic content in most of the crops than other plant parts. Similar type of findings was earlier reported by Streit and Stumm (1993). However, in case of elephant-foot yam and potato, the economic/edible portions, in spite of being underground, recorded lower concentration of arsenic compared with the above ground portions such as stem and leaf and thereby assuring less toxicity in favour of human consumption.

Among the crops tried during the lean summer months, summer rice recorded the highest values of arsenic concentration in different plant parts. Rice stem, normally fed to the cattle as straw, showed high values of arsenic content which might lead to serious poisoning and health hazards for the dairy animals in the locality.

Effect of cropping sequences on arsenic build-up by crops was less pronounced; however, there was some variations. Maize recorded lower values in seeds when grown after potato than after elephant-foot yam. Elephant-foot yam recorded lower values in corm with sequence 3 during 2nd and 3rd years of experimentation (grown after sesame) while it was in sequence 10 in 1st year (grown after greengram). Jute showed high values of arsenic build-up in sequence 5 when grown after summer rice than when grown after sesame in sequence 4. The wet season rice recorded lower values in grains when grown after green manure in sequence 8 in all the 3 years of cropping. Summer rice recorded lower values in grains in sequence 8, which might be due to the positive effect of green manure in binding soil arsenic.

The most important and alarming point noted was that most of the crops showed progressively increasing values of arsenic concentration in different plant parts in unequal proportions over the years.

# TABLE 4.101

## Arsenic content in different plant parts of crops in different systems of cropping at 30 DBH in 1998-1999

| Cropping sequence | Arsenic concentration (mg kg$^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 4.53 | 5.00 | 5.12 | 1.90 | 4.70 | 4.97 | 3.53 | - | 4.70 | 7.23 | - | 4.13 | | | | |
| 2. E-M-G | 4.00 | 4.13 | - | 4.03 | 4.90 | 5.10 | 5.13 | 2.12 | 3.83 | 4.83 | 4.94 | - | | | | |
| 3.E-Md-S | 3.90 | 4.05 | - | 3.98 | 6.90 | 8.97 | 5.17 | 3.00 | 1.70 | 2.06 | 3.93 | 0.42 | | | | |
| 4. Jo-G-P-S | 4.10 | 6.92 | 7.91 | 3.00 | 4.13 | 4.50 | 3.90 | - | 4.94 | 8.40 | - | 3.83 | 2.00 | 1.98 | 3.95 | 0.40 |
| 5. Jo-Ra-Rb | 4.28 | 6.21 | 8.27 | 3.21 | 4.73 | 5.02 | 5.61 | 4.37 | 5.82 | 6.37 | 7.02 | 7.91 | | | | |
| 6. E-W-Gn | 4.13 | 4.06 | - | 3.76 | 3.86 | 4.12 | 6.93 | 2.70 | 1.81 | 2.00 | 1.97 | 3.72 | | | | |
| 7. G-Ra-Md | 3.83 | 4.19 | 3.90 | - | 4.00 | 4.80 | 6.27 | 4.00 | 6.40 | 7.98 | 5.22 | 2.17 | | | | |
| 8. Gm-Ra-Rb | - | - | - | - | 3.71 | 4.78 | 6.13 | 3.29 | 4.83 | 6.14 | 6.23 | 7.00 | | | | |
| 9. M(Gi)-G-P | 4.59 | 5.00 | 5.13 | 1.82 | 4.47 | 4.83 | 3.10 | - | 4.82 | 7.43 | - | 3.92 | | | | |
| | *(4.00) | (4.23) | (4.83) | (-) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 4.05 | 4.06 | - | 3.51 | 5.00 | 5.10 | 5.23 | 2.00 | 3.70 | 4.12 | 3.93 | - | | | | |
| | *(4.13) | (4.54) | (3.17) | (-) | | | | | | | | | | | | |

* Intercrop value

## TABLE 4.102

**Arsenic content in different plant parts of crops in different systems of cropping at 15 DBH in 1998-1999**

| Cropping sequence | Arsenic concentration (mg $kg^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 5.03 | 5.23 | 5.31 | 2.10 | 4.90 | 5.07 | 3.90 | 4.00 | 5.09 | 8.19 | - | 4.41 | | | | |
| 2. E-M-G | 4.30 | 4.60 | - | 4.50 | 5.40 | 5.10 | 5.39 | 2.24 | 4.09 | 5.10 | 5.17 | 3.43 | | | | |
| 3.E-Md-S | 4.10 | 4.42 | - | 4.60 | 7.10 | 10.50 | 5.40 | 3.00 | 2.00 | 2.20 | 4.10 | 0.50 | | | | |
| 4. Jo-G-P-S | 4.70 | 7.00 | 8.13 | 3.73 | 4.29 | 4.73 | 3.81 | 3.13 | 5.30 | 9.30 | - | 4.68 | 2.00 | 2.01 | 4.00 | 0.42 |
| 5. Jo-Ra-Rb | 4.76 | 6.91 | 8.68 | 4.00 | 4.96 | 5.40 | 7.12 | 4.86 | 6.06 | 6.70 | 7.61 | 8.00 | | | | |
| 6. E-W-Gn | 4.23 | 4.51 | - | 4.32 | 4.10 | 4.23 | 7.95 | 3.00 | 2.00 | 2.00 | 2.00 | 4.00 | | | | |
| 7. G-Ra-Md | 4.19 | 4.64 | 3.82 | 3.07 | 4.10 | 5.13 | 6.71 | 4.10 | 7.00 | 8.30 | 5.80 | 2.67 | | | | |
| 8. Gm-Ra-Rb | 4.00 | 7.10 | 8.91 | - | 4.00 | 5.00 | 6.51 | 3.93 | 6.00 | 6.51 | 6.91 | 7.14 | | | | |
| 9. M(Gi)-G-P | 5.20 | 5.10 | 5.21 | 2.00 | 4.72 | 5.00 | 3.24 | 3.85 | 5.10 | 8.00 | - | 4.13 | | | | |
| | *(4.27) | (4.70) | (5.01) | (3.59) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 4.45 | 4.12 | - | 3.93 | 5.17 | 5.35 | 5.41 | 2.10 | 4.00 | 4.53 | 4.95 | 3.17 | | | | |
| | *(4.90) | (5.10) | (3.90) | 4.00 | | | | | | | | | | | | |

* Intercrop value

## TABLE 4.103

**Arsenic content in different plant parts of crops in different systems of cropping at harvest in 1998-1999**

| Cropping sequence | Arsenic concentration (mg kg$^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 5.13 | 5.21 | 5.47 | 2.21 | 5.01 | 5.40 | 3.98 | 4.52 | 3.94 | 9.34 | - | 5.88 | | | | |
| 2. E-M-G | 4.38 | 4.70 | - | 4.85 | 5.42 | 5.30 | 5.52 | 2.90 | 4.53 | 4.74 | 3.63 | 4.15 | | | | |
| 3.E-Md-S | 4.18 | 4.62 | - | 4.08 | 7.12 | 9.80 | 5.72 | 3.36 | 2.00 | 2.00 | 4.00 | 0.60 | | | | |
| 4. Jo-G-P-S | 4.23 | 7.16 | 9.00 | 3.92 | 4.91 | 5.10 | 3.90 | 4.27 | 3.18 | 7.80 | - | 4.97 | 2.00 | 2.10 | 3.76 | 0.52 |
| 5. Jo-Ra-Rb | 4.74 | 7.60 | 9.12 | 4.00 | 5.00 | 5.42 | 7.10 | 4.71 | 6.10 | 6.98 | 7.39 | 8.10 | | | | |
| 6. E-W-Gn | 4.23 | 4.60 | - | 4.47 | 4.29 | 4.47 | 8.00 | 3.26 | 2.00 | 2.00 | 2.20 | 4.00 | | | | |
| 7. G-Ra-Md | 5.00 | 5.25 | 3.17 | 4.10 | 4.69 | 5.10 | 6.92 | 4.30 | 6.17 | 10.15 | 5.17 | 3.10 | | | | |
| 8. Gm-Ra-Rb | 4.23 | 8.17 | 9.89 | - | 4.10 | 5.00 | 7.55 | 4.13 | 6.00 | 6.73 | 7.40 | 7.84 | | | | |
| 9. M(Gi)-G-P | 5.04 | 5.24 | 5.36 | 2.20 | 5.00 | 5.23 | 3.90 | 4.54 | 3.90 | 9.47 | - | 5.99 | | | | |
| | *(4.47) | (5.10) | (5.23) | (4.00) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 4.10 | 4.53 | - | 4.10 | 5.40 | 5.17 | 5.50 | 2.82 | 4.17 | 4.60 | 3.51 | 4.00 | | | | |
| | *(5.60) | (5.04) | (3.98) | (4.52) | | | | | | | | | | | | |

* Intercrop value

## TABLE 4.104

**Arsenic content in different plant parts of crops in different systems of cropping at 30 DBH in 1999-2000**

| Cropping sequence | Arsenic concentration ($mg\ kg^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 2.78 | 7.03 | 2.86 | 1.79 | 3.42 | 3.83 | 4.10 | - | 5.19 | 8.17 | - | 4.01 | | | | |
| 2. E-M-G | 3.79 | 10.10 | - | 3.71 | 2.59 | 7.64 | 3.10 | 1.90 | 3.31 | 3.60 | 3.98 | - | | | | |
| 3.E-Md-S | 3.91 | 9.76 | - | 3.79 | 6.93 | 6.12 | 6.79 | 2.18 | 2.43 | 2.61 | 4.19 | 0.92 | | | | |
| 4. Jo-G-P-S | 3.00 | 7.13 | 8.63 | 3.21 | 3.30 | 3.73 | 3.90 | - | 5.23 | 9.10 | - | 4.16 | 2.54 | 2.60 | 4.32 | 1.00 |
| 5. Jo-Ra-Rb | 3.17 | 7.31 | 8.79 | 3.40 | 4.62 | 5.43 | 5.91 | 7.01 | 5.12 | 5.31 | 5.40 | 8.10 | | | | |
| 6. E-W-Gn | 3.82 | 10.21 | - | 3.63 | 4.39 | 4.78 | 10.37 | 2.71 | 2.14 | 2.31 | 2.36 | 4.07 | | | | |
| 7. G-Ra-Md | 3.07 | 3.71 | 4.00 | - | 4.34 | 5.12 | 5.43 | 6.73 | 6.70 | 6.10 | 6.67 | 2.03 | | | | |
| 8. Gm-Ra-Rb | - | - | - | - | 4.10 | 4.77 | 4.96 | 6.12 | 4.90 | 5.27 | 5.30 | 7.09 | | | | |
| 9. M(Gi)-G-P | 2.90 | 7.41 | 3.08 | 1.99 | 3.40 | 3.73 | 3.90 | - | 5.03 | 7.97 | - | 4.00 | | | | |
| | *(3.27) | (3.56) | (3.83) | (-) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 3.91 | 9.13 | - | 3.60 | 2.43 | 7.61 | 3.10 | 1.78 | 3.19 | 3.53 | 3.81 | - | | | | |
| | *(4.17) | (5.21) | (4.91) | (-) | | | | | | | | | | | | |

* Intercrop value

## TABLE 4.105

**Arsenic content in different plant parts of crops in different systems of cropping at 15 DBH in 1999-2000**

| Cropping sequence | Arsenic concentration (mg $kg^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 3.06 | 8.00 | 3.00 | 2.00 | 4.12 | 4.79 | 4.56 | 3.00 | 5.60 | 9.00 | - | 4.39 | | | | |
| 2. E-M-G | 4.10 | 12.00 | - | 4.00 | 3.10 | 7.60 | 3.10 | 2.20 | 4.18 | 4.76 | 4.60 | 2.90 | | | | |
| 3.E-Md-S | 4.00 | 11.70 | - | 4.16 | 7.68 | 6.80 | 6.60 | 2.98 | 2.80 | 2.72 | 4.60 | 1.04 | | | | |
| 4. Jo-G-P-S | 3.54 | 7.80 | 9.09 | 3.91 | 4.32 | 4.80 | 4.59 | 2.82 | 5.50 | 9.10 | - | 4.90 | 2.80 | 2.80 | 4.58 | 1.06 |
| 5. Jo-Ra-Rb | 3.42 | 8.00 | 10.00 | 4.00 | 5.06 | 6.32 | 6.90 | 9.71 | 5.42 | 5.32 | 5.52 | 10.00 | | | | |
| 6. E-W-Gn | 4.10 | 12.00 | - | 4.20 | 5.00 | 5.20 | 12.00 | 3.10 | 2.40 | 2.40 | 2.31 | 4.30 | | | | |
| 7. G-Ra-Md | 4.28 | 4.72 | 4.49 | 2.70 | 5.00 | 6.12 | 6.81 | 9.41 | 7.60 | 6.96 | 6.52 | 2.70 | | | | |
| 8. Gm-Ra-Rb | 4.70 | 9.29 | 11.27 | - | 4.91 | 5.98 | 6.27 | 5.47 | 5.23 | 5.40 | 5.27 | 9.10 | | | | |
| 9. M(Gi)-G-P | 3.09 | 8.00 | 3.10 | 2.20 | 4.10 | 4.60 | 4.62 | 3.00 | 5.60 | 9.12 | - | 4.40 | | | | |
| | *(4.12) | (4.46) | (4.60) | (2.96) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 4.08 | 11.90 | - | 4.06 | 3.10 | 7.29 | 3.10 | 2.10 | 4.10 | 4.72 | 4.80 | 2.92 | | | | |
| | *(4.90) | (5.40) | (5.10) | (2.20) | | | | | | | | | | | | |

* Intercrop value

**TABLE 4.106**

**Arsenic content in different plant parts of crops in different systems of cropping at harvest in 1999-2000**

| Cropping sequence | Arsenic concentration (mg kg$^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 3.30 | 8.10 | 5.20 | 2.53 | 5.08 | 4.90 | 4.70 | 4.30 | 4.20 | 9.00 | - | 4.68 | | | | |
| 2. E-M-G | 4.30 | 8.00 | - | 4.00 | 3.26 | 8.20 | 5.10 | 2.60 | 5.07 | 4.98 | 4.70 | 4.16 | | | | |
| 3.E-Md-S | 4.10 | 7.92 | - | 3.70 | 6.82 | 7.00 | 6.03 | 3.10 | 2.10 | 3.10 | 4.78 | 1.52 | | | | |
| 4. Jo-G-P-S | 3.12 | 7.82 | 6.80 | 3.77 | 5.00 | 4.70 | 4.70 | 4.02 | 4.03 | 9.16 | - | 4.98 | 2.03 | 3.00 | 4.59 | 1.60 |
| 5. Jo-Ra-Rb | 3.50 | 8.00 | 6.76 | 4.00 | 3.20 | 6.40 | 7.02 | 6.80 | 10.24 | 5.72 | 5.92 | 10.00 | | | | |
| 6. E-W-Gn | 4.23 | 8.00 | - | 3.89 | 5.10 | 5.20 | 12.00 | 3.16 | 2.60 | 2.40 | 2.46 | 4.80 | | | | |
| 7. G-Ra-Md | 5.10 | 4.90 | 4.68 | 4.26 | 5.12 | 6.10 | 7.00 | 5.81 | 6.90 | 7.00 | 6.10 | 3.00 | | | | |
| 8. Gm-Ra-Rb | 5.70 | 10.44 | 12.09 | - | 5.06 | 6.36 | 6.92 | 5.70 | 10.10 | 5.23 | 5.70 | 9.75 | | | | |
| 9. M(Gi)-G-P | 3.30 | 8.06 | 5.16 | 2.60 | 5.10 | 4.73 | 4.62 | 4.28 | 4.10 | 8.72 | - | 4.60 | | | | |
| | *(4.90) | (4.92) | (4.62) | (4.23) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 4.30 | 7.82 | - | 4.00 | 3.23 | 7.19 | 5.02 | 2.42 | 4.92 | 4.75 | 4.53 | 4.01 | | | | |
| | (4.91) | (5.10) | (5.20) | (2.10) | | | | | | | | | | | | |

* Intercrop value

## TABLE 4.107

**Arsenic content in different plant parts of crops in different systems of cropping at 30 DBH in 2000-2001**

| Cropping sequence | Arsenic concentration (mg $kg^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 2.84 | 6.83 | 5.41 | 1.82 | 4.13 | 4.32 | 4.63 | - | 4.70 | 6.34 | - | 3.41 | | | | |
| 2. E-M-G | 3.82 | 7.76 | - | 3.53 | 2.80 | 6.41 | 5.31 | 1.94 | 3.98 | 4.10 | 4.53 | - | | | | |
| 3.E-Md-S | 3.52 | 7.42 | - | 3.30 | 6.17 | 5.71 | 6.43 | 2.14 | 1.53 | 2.17 | 3.59 | 1.06 | | | | |
| 4. Jo-G-P-S | 2.91 | 7.17 | 8.67 | 3.82 | 4.00 | 4.17 | 4.47 | - | 4.52 | 6.49 | - | 3.60 | 1.71 | 3.10 | 4.17 | 1.13 |
| 5. Jo-Ra-Rb | 3.24 | 8.12 | 9.23 | 3.71 | 4.61 | 5.39 | 6.78 | 7.98 | 7.51 | 7.00 | 7.91 | 8.74 | | | | |
| 6. E-W-Gn | 3.64 | 7.69 | - | 3.43 | 4.39 | 5.91 | 12.09 | 2.16 | 2.00 | 2.12 | 2.83 | 3.46 | | | | |
| 7. G-Ra-Md | 3.83 | 4.17 | 4.27 | - | 4.33 | 5.47 | 6.50 | 7.31 | 5.92 | 5.63 | 6.14 | 2.23 | | | | |
| 8. Gm-Ra-Rb | - | - | - | - | 4.10 | 5.54 | 6.13 | 5.03 | 7.23 | 6.45 | 7.43 | 7.90 | | | | |
| 9. M(Gi)-G-P | 2.69 | 6.54 | 5.23 | 1.80 | 4.17 | 4.21 | 4.43 | - | 4.53 | 6.30 | - | 3.17 | | | | |
| | *(3.63) | (4.12) | (4.39) | (-) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 3.80 | 7.43 | - | 1.76 | 2.43 | 6.10 | 3.24 | 1.73 | 3.41 | 4.00 | 4.23 | - | | | | |
| | *(4.12) | (5.32) | (5.63) | (-) | | | | | | | | | | | | |

* Intercrop value

**Table 4.108**

**Arsenic content in different plant parts of crops in different systems of cropping at 15 DBH in 2000-2001**

| Cropping sequence | Arsenic concentration (mg $kg^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 3.15 | 7.20 | 5.66 | 2.12 | 4.70 | 4.80 | 4.92 | 2.90 | 5.16 | 7.69 | - | 4.07 | | | | |
| 2. E-M-G | 4.52 | 8.22 | - | 4.03 | 3.05 | 6.93 | 5.28 | 2.10 | 4.51 | 4.90 | 4.93 | 3.00 | | | | |
| 3.E-Md-S | 4.37 | 8.23 | - | 4.00 | 6.92 | 6.31 | 7.10 | 2.70 | 2.00 | 2.72 | 4.67 | 1.40 | | | | |
| 4. Jo-G-P-S | 3.43 | 8.78 | 9.78 | 4.12 | 4.62 | 4.89 | 4.91 | 3.12 | 4.90 | 7.89 | - | 4.10 | 2.10 | 2.69 | 5.00 | 1.60 |
| 5. Jo-Ra-Rb | 3.60 | 9.00 | 10.60 | 4.00 | 5.10 | 6.34 | 7.26 | 8.76 | 8.10 | 7.10 | 8.32 | 9.37 | | | | |
| 6. E-W-Gn | 4.49 | 8.14 | - | 4.10 | 5.69 | 6.90 | 13.12 | 3.20 | 2.10 | 2.23 | 3.00 | 4.10 | | | | |
| 7. G-Ra-Md | 4.10 | 4.64 | 4.81 | 3.03 | 5.00 | 6.12 | 7.12 | 8.30 | 6.82 | 6.23 | 7.01 | 2.81 | | | | |
| 8. Gm-Ra-Rb | 4.83 | 9.40 | 12.24 | - | 5.05 | 6.02 | 6.90 | 5.12 | 7.74 | 6.99 | 8.13 | 9.00 | | | | |
| 9. M(Gi)-G-P | 3.10 | 7.12 | 5.69 | 2.06 | 4.20 | 4.50 | 4.60 | 2.90 | 5.10 | 7.80 | - | 4.00 | | | | |
| | *(4.43) | (4.67) | (4.84) | (2.94) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 4.46 | 7.02 | - | 2.04 | 2.91 | 7.62 | 3.98 | 2.01 | 4.30 | 4.20 | 4.60 | 3.00 | | | | |
| | *(4.92) | (5.56) | (5.74) | (2.30) | | | | | | | | | | | | |

* Intercrop value

## TABLE 4.109

**Arsenic content in different plant parts of crops in different systems of cropping at harvest in 2000-2001**

| Cropping sequence | Arsenic concentration ($mg\ kg^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st crop | | | | 2nd crop | | | | 3rd crop | | | | 4th crop | | | |
| | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce | Leaf | Stem | Root | Economic produce |
| 1. M-G-P | 3.80 | 6.19 | 6.32 | 2.10 | 5.20 | 5.70 | 5.98 | 4.01 | 5.20 | 7.62 | - | 4.07 | | | | |
| 2. E-M-G | 4.60 | 8.00 | - | 4.23 | 3.71 | 5.69 | 6.10 | 2.38 | 5.28 | 5.63 | 6.00 | 4.10 | | | | |
| 3.E-Md-S | 4.41 | 8.10 | - | 3.84 | 6.96 | 7.00 | 7.23 | 2.90 | 2.02 | 2.67 | 5.60 | 1.42 | | | | |
| 4. Jo-G-P-S | 3.60 | 7.92 | 10.60 | 4.00 | 5.01 | 5.63 | 6.00 | 3.90 | 5.03 | .80 | - | 4.19 | 2.12 | 2.83 | 5.60 | 1.60 |
| 5. Jo-Ra-Rb | 3.50 | 9.00 | 10.12 | 4.12 | 5.12 | 6.30 | 8.23 | 5.90 | 8.42 | 7.32 | 8.30 | 10.00 | | | | |
| 6. E-W-Gn | 4.53 | 8.30 | - | 3.90 | 5.80 | 6.90 | 14.00 | 3.26 | 2.12 | 2.43 | 3.10 | 4.10 | | | | |
| 7. G-Ra-Md | 5.20 | 5.52 | 5.98 | 4.07 | 4.93 | 6.16 | 7.23 | 6.98 | 6.71 | 6.91 | 7.11 | 2.71 | | | | |
| 8. Gm-Ra-Rb | 6.13 | 11.47 | 13.10 | - | 4.39 | 5.79 | 7.19 | 5.80 | 8.10 | 6.91 | 7.90 | 9.10 | | | | |
| 9. M(Gi)-G-P | 3.23 | 8.13 | 5.10 | 2.54 | 5.10 | 5.70 | 5.93 | 3.93 | 5.02 | 7.43 | - | 4.00 | | | | |
| | *(5.28) | (5.61) | (6.00) | (3.93) | | | | | | | | | | | | |
| 10. E(Ci)-M-G | 4.60 | 7.94 | - | 4.14 | 3.81 | 5.81 | 6.24 | 2.30 | 5.10 | 5.41 | 5.73 | 4.04 | | | | |
| | *(5.00) | (5.38) | (610) | (2.26) | | | | | | | | | | | | |

* Intercrop value

### 4.7.2 Total arsenic uptake by the crops in different systems of cropping

#### 4.7.2.1 Arsenic uptake by greengram

Results summarised in Table 4.110 showed variation in total As uptake by greengram in different systems even in a single year as well as in all the three years of cropping (Fig. 20). These variations might be due to the differences in arsenic content (*i.e.,* As concentration) in different plant parts of the crop over the years Greengram grown as intercrop alongwith maize in sequence 9 recorded the lowest uptake which might be due to the fact that the main crop of maize resulted comparatively in higher arsenic uptake and thereby benefitted the intercrop in respect of lower As uptake. Greengram grown after maize in sequence 10 recorded the lowest uptake among the sole greengram crops followed by sequence 7 (grown after mustard) in 1$^{st}$ year; while sequence 1 recorded the lowest uptake in other two years of cropping. Greengram grown after maize recorded comparatively lower arsenic uptake in sequences 1 and 2 in all the three years of cropping in view of heavy uptake by maize which, in turn, reduced As uptake by the succeeding crop.

#### 4.7.2.2 Arsenic uptake by potato

Variation in arsenic uptake by potato grown in different cropping sequences was significant in 1$^{st}$ and 3$^{rd}$ year of cropping. Arsenic uptake by potato showed slight variation among the years of cropping. However, potato grown after greengram in sequence 1 recorded the maximum uptake (Table 4.111; Fig. 21). Comparatively lower uptake was noted by potato in sequence 4 during 1$^{st}$ year.

#### 4.7.2.3 Arsenic uptake by rice

Arsenic uptake by rice (Table 4.112; Fig. 22) showed significant variation in different systems of cropping. Uptake of arsenic by summer rice was double or even more compared with the uptake by winter rice in all the years of cropping. However, variation was very low among the rices grown in different sequences of cropping within a particular season during both winter (*aman*) and summer (*boro*). The winter rice, grown after greengram (sequence 7), recorded the lowest uptake in 1$^{st}$ year while it was in sequence 5 (grown after jute) in the other two years of cropping. Summer rice grown after winter rice in sequence 5 showed the highest uptake in all the years

Plate 23 : Mustard at flowering stage in sequence 3

Plate 24 : Mustard in sequence 7 at flowering stage

Plate 25 : Groundnut at branching stage in sequence 6 (1998-1999)

Plate 26 : Groundnut in sequence 6 (2000-2001)

of cropping. Higher As uptake by summer rice might be due to the fact that higher volume of water, required by it, especially groundwater, during the lean months resulting greater mobilisation of arsenic in both soil and water thereby causing greater availability and hence uptake by the crop.

#### 4.7.2.4 Arsenic uptake by maize

Maize showed relatively higher arsenic uptake in all the three years of cropping. There was significant variation of arsenic uptake in different systems of cropping (Fig. 23). Being a heavy feeder, it had resulted in higher uptake. Maize grown after elephant-foot yam recorded the lowest uptake during the first two years (sequence 10) while sequence 2 showed the lowest uptake in 3$^{rd}$ year (Table 4.113). Uptake of arsenic was higher in maize grown in summer (sequences 1 and 9) than when grown in winter (sequences 2 and 10).

#### 4.7.2.5 Arsenic uptake by jute

Jute showed very high values of arsenic uptake in all the three years of cropping (Table 4.114; Fig. 24). It showed gradual increase in As uptake over the years. Jute, grown after *boro* rice in sequence 5 (Jo-Ra-Rb), recorded the highest value in all the three years of cropping than jute grown after sesame. High dry matter at harvest might had resulted in higher uptake by jute compared with the other crops. Growing jute in different systems of cropping showed significant variation in 1$^{st}$ and 3$^{rd}$ year.

#### 4.7.2.6 Arsenic uptake by mustard

Mustard recorded relatively lower arsenic uptake (Table 4.115) than either rice or jute. The variation between the cropping sequences and among the years were also very negligible. However, mustard grown after winter rice (sequence 7) showed slightly lower values in 1$^{st}$ and in 3$^{rd}$ year (Fig. 25).

#### 4.7.2.7 Arsenic uptake by sesame

Uptake of arsenic was the lowest in sesame among all the crops tried in various cropping sequences. Besides, sequences of cropping had little influence on arsenic uptake by sesame. The highest and the lowest uptake were found in sequence

## TABLE 4.110

### Arsenic uptake by greengram in different systems of cropping

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 22.83 | 11.21 | 16.60 |
| 2. E-M-G | 13.45 | 17.71 | 18.53 |
| 4. Jo-G-P-S | 23.48 | 20.40 | 23.57 |
| 7. G-Ra-Md | 12.88 | 13.96 | 28.64 |
| 9. M(Gi)-G-P | *(9.35) | (7.72) | (13.35) |
| | 21.72 | 25.68 | 16.95 |
| 10. E(Ci)-M-G | 12.48 | 17.30 | 18.82 |
| SEm (±) | 0.51 | 0.43 | 0.61 |
| CD at 5% | 1.57 | 1.32 | 1.87 |

* Intercrop value

## TABLE 4.111

### Arsenic uptake by potato in different systems of cropping

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 38.40 | 31.54 | 29.76 |
| 4. Jo-G-P-S | 23.96 | 30.67 | 27.30 |
| 9. M(Gi)-G-P | 35.92 | 30.23 | 27.96 |
| SEm (±) | 0.59 | 0.43 | 0.41 |
| CD at 5% | 2.31 | NS | 1.60 |

## TABLE 4.112

### Arsenic uptake by rice in different systems of cropping

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| ➢ *Aman* | | | |
| 5. Jo-Ra-Rb | 31.80 | 52.97 | 50.90 |
| 7. G-Ra-Md | 27.40 | 58.09 | 57.87 |
| 8. Gm-Ra-Rb | 29.78 | 58.04 | 54.57 |
| ➢ *Boro* | | | |
| 5. Jo-Ra-Rb | 75.32 | 76.21 | 77.65 |
| 8. Gm-Ra-Rb | 74.76 | 75.35 | 74.13 |
| SEm (±) | 0.43 | 0.62 | 0.90 |
| CD at 5% | 1.40 | 2.02 | 2.93 |

## TABLE 4.113

### Arsenic uptake by maize in different systems of cropping

| Cropping sequence | Arsenic uptake (g ha$^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 54.77 | 72.11 | 60.03 |
| 2. E-M-G | 48.41 | 67.02 | 52.72 |
| 9. M(Gi)-G-P | 54.40 | 72.00 | 39.43 |
| 10. E(Ci)-M-G | 46.58 | 60.74 | 52.81 |
| SEm (±) | 0.65 | 0.82 | 0.49 |
| CD at 5% | 2.24 | 2.83 | 1.69 |

## TABLE 4.114

### Arsenic uptake by jute in different systems of cropping

| Cropping sequence | Arsenic uptake (g ha$^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 4. Jo-G-P-S | 58.34 | 60.99 | 84.74 |
| 5. Jo-Ra-Rb | 69.08 | 62.16 | 99.63 |
| 't' value | 7.42 * | 1.89 NS | 12.15 * |

* Significant

## TABLE 4.115

### Arsenic uptake by mustard in different systems of cropping

| Cropping sequence | Arsenic uptake (g ha$^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 3. E-Md-S | 32.61 | 27.64 | 31.76 |
| 7. G-Ra-Md | 26.15 | 31.06 | 28.41 |
| 't' value | 10.47 NS | 5.54 NS | 5.43 NS |

## TABLE 4.116

### Arsenic uptake by sesame in different systems of cropping

| Cropping sequence | Arsenic uptake (g ha$^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 3. E-Md-S | 6.54 | 7.69 | 7.05 |
| 4. Jo-G-P-S | 5.15 | 7.03 | 7.91 |
| 't' value | 2.25 NS | 1.07 NS | 1.39 NS |

## TABLE 4.117

### Arsenic uptake by groundnut

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 6. E-W-Gn | 14.76 | 18.46 | 15.00 |

## TABLE 4.118

### Arsenic uptake by wheat

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 6. E-W-Gn | 37.27 | 44.96 | 58.21 |

## TABLE 4.119

### Arsenic uptake by elephant-foot yam in different systems of cropping

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 2. E-M-G | 34.00 | 46.94 | 60.23 |
| 3. E-Md-S | 25.66 | 54.09 | 55.97 |
| 6. E-W-Gn | 36.67 | 39.63 | 50.94 |
| 10. E(Ci)-M-G | 28.27 | 47.02 | 61.03 |
| SEm (±) | 0.53 | 0.49 | 0.70 |
| CD at 5% | 1.83 | 1.69 | 2.42 |

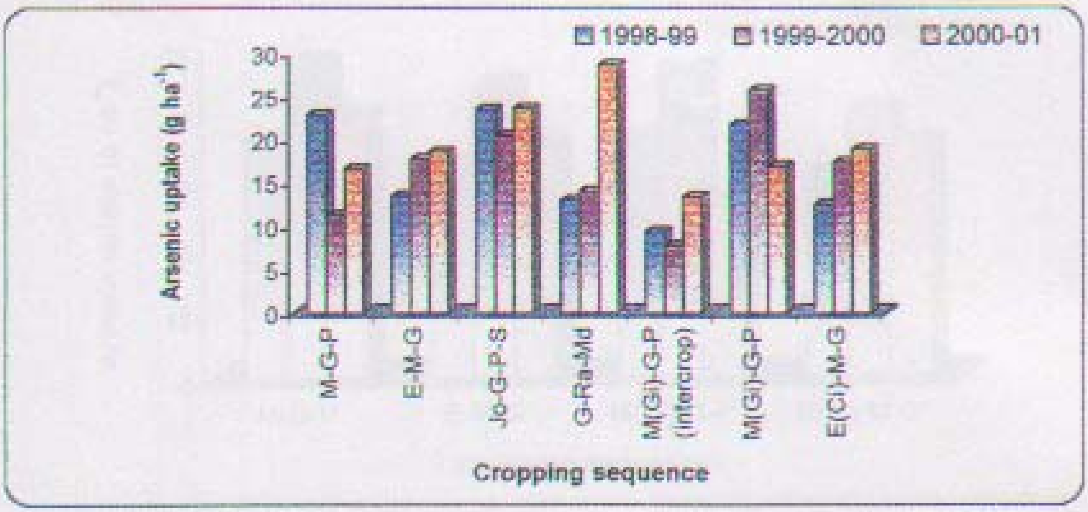



Fig. 20 : Arsenic uptake by greengram in different systems of cropping

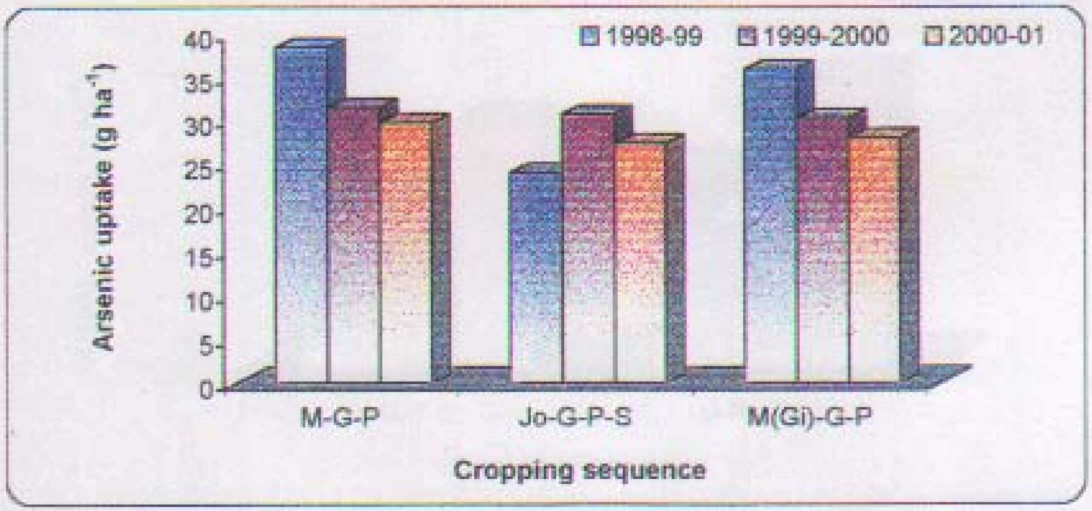



Fig. 21 : Arsenic uptake by potato in different systems of cropping

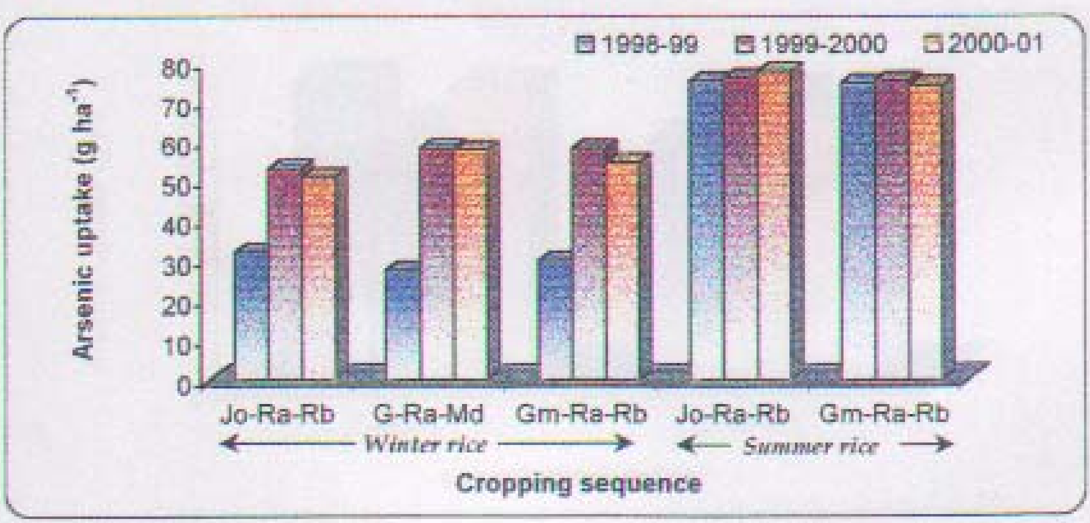



Fig. 22 : Arsenic uptake by rice in different systems of cropping

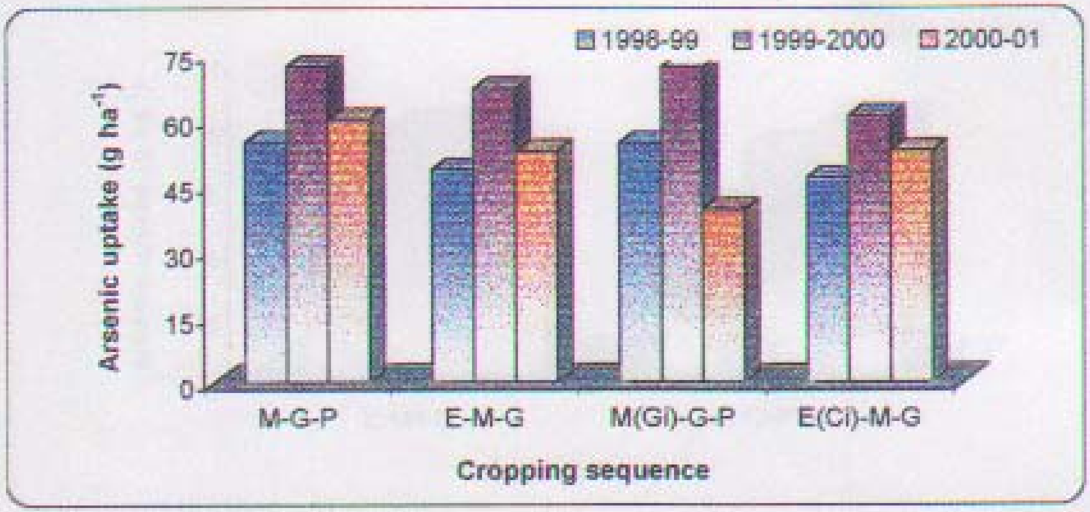



**Fig. 23 : Arsenic uptake by maize in different systems of cropping**

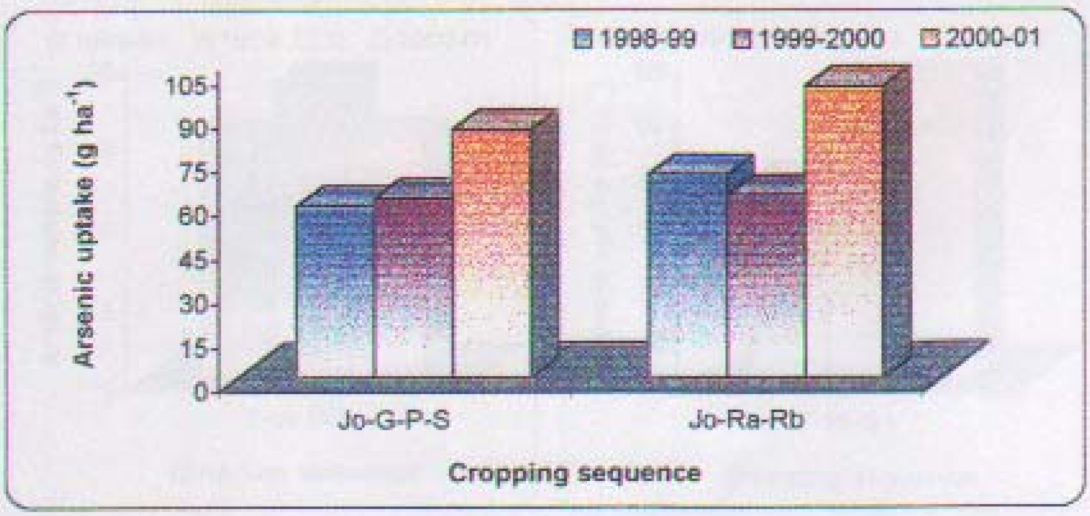



**Fig. 24 : Arsenic uptake by jute in different systems of cropping**

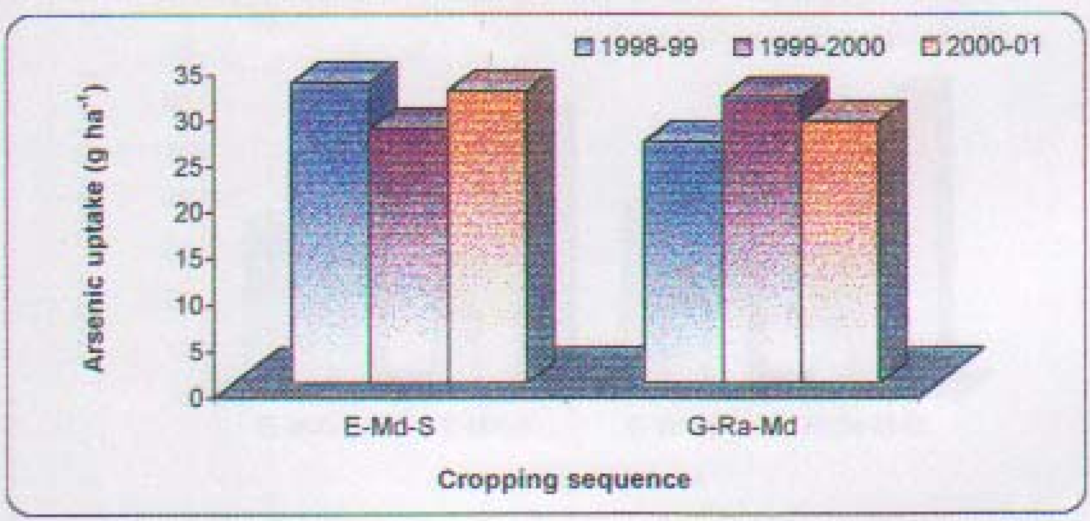



**Fig. 25 : Arsenic uptake by mustard in different systems of cropping**

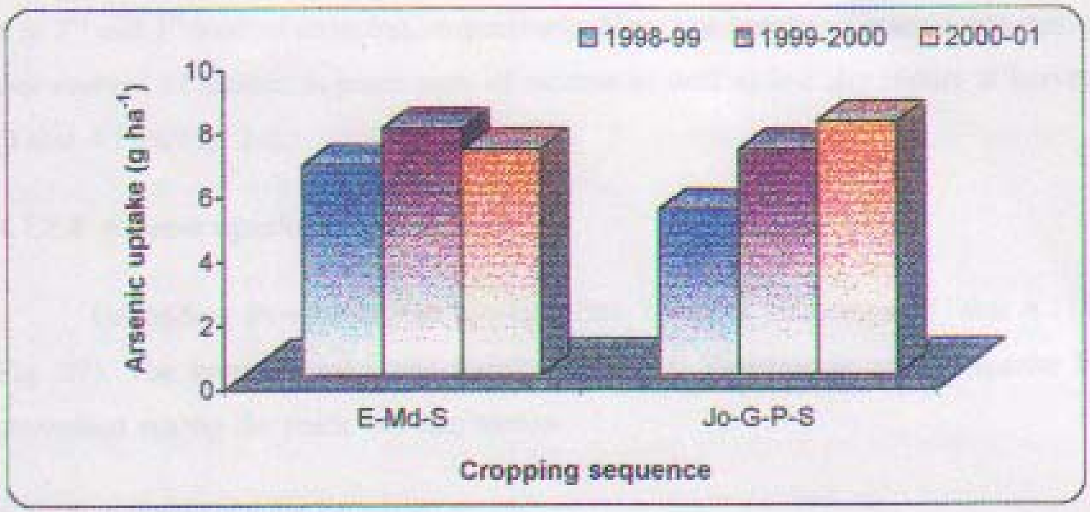
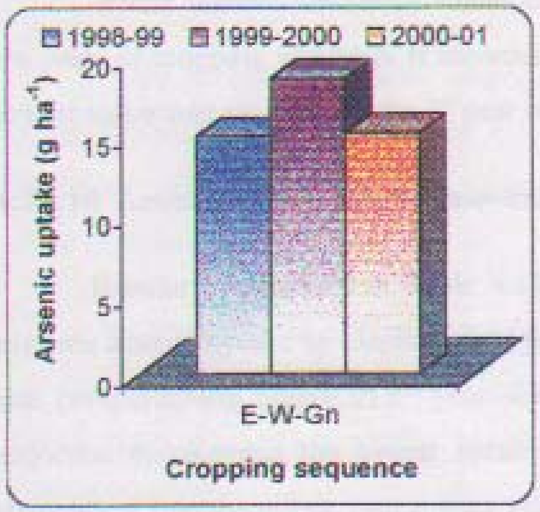



**Fig. 26 : Arsenic uptake by sesame in different systems of cropping**



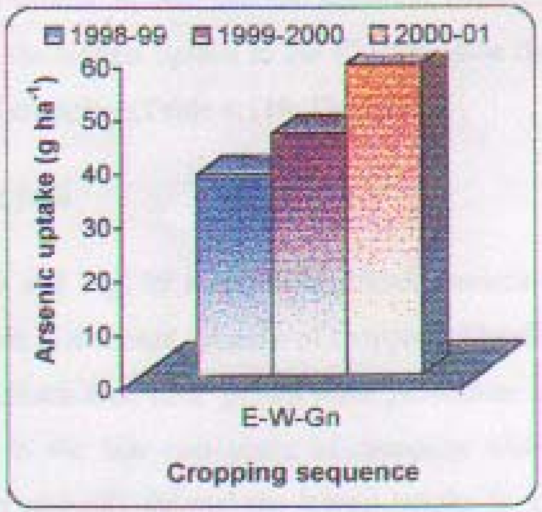




**Fig. 27 : Arsenic uptake by groundnut Fig. 28 : Arsenic uptake by wheat**

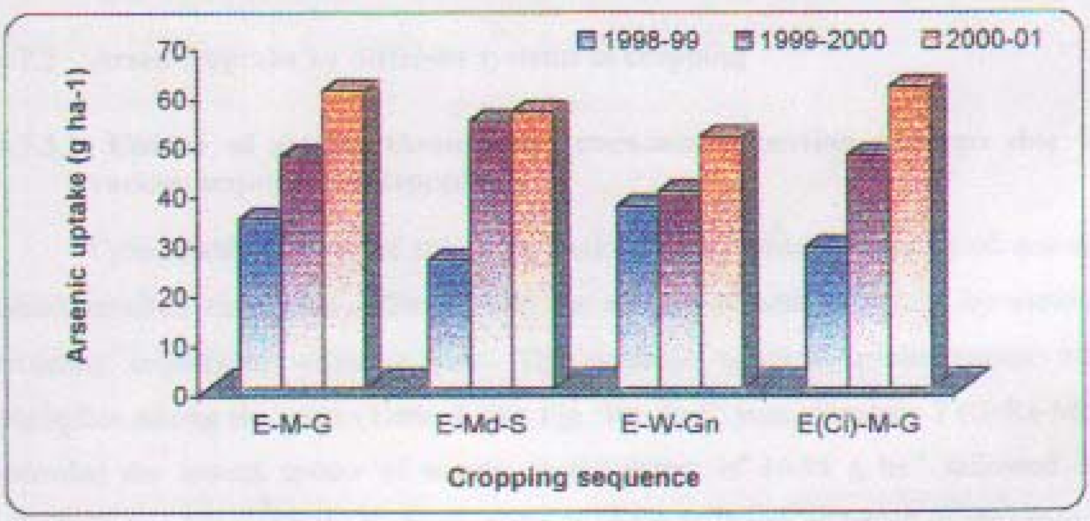



**Fig. 29 : Arsenic uptake by elephant-foot yam in different systems of cropping**

4 in 3rd and 1st year of cropping, respectively. Very low uptake of arsenic was due to low content of arsenic in plant parts of sesame as well as low dry matter at harvest (Table 4.116; Fig. 26).

#### 4.7.2.8 Arsenic uptake by groundnut

Groundnut showed arsenic uptake a little bit more than sesame (Table 4.117; Fig. 27). The lowest uptake was found in 1st year. Variation in arsenic uptake by groundnut among the years was also narrow.

#### 4.7.2.9 Arsenic uptake by wheat

*Wheat showed moderate values of arsenic uptake but the variation between* the years of cropping was high. It recorded the highest uptake in the 3rd year while the lowest value was recorded in the 1st year of cropping (Table 4.118; Fig. 28).

#### 4.7.2.10 Arsenic uptake by elephant-foot yam

Results summarised in Table 4.119 and Fig. 29 showed significant variation towards arsenic uptake by elephant-foot yam in different systems of cropping. Uptake was comparatively higher in 3rd year. Elephant-foot yam, grown after groundnut in sequence 6, recorded the lowest uptake in the last two years of cropping while sequence 3 (elephant-foot yam grown after sesame) showed the lowest uptake in 1st year.

### 4.7.3 Arsenic uptake by different systems of cropping

#### 4.7.3.1 Uptake of arsenic through the consumable portion of crops due to various sequences of cropping

Consumable portion of the crops varied widely towards content of arsenic which resulted significant differences in the amount of arsenic uptake by various cropping sequences, within a year. The variation towards uptake values was negligible among the years (Table 4.120; Fig. 30). In 1st year, sequence 7 (G-Ra-Md) recorded the lowest uptake of arsenic to the extent of 16.94 g $ha^{-1}$ followed by sequence 4 and 3; while the highest uptake (57.54 g $ha^{-1}$) was observed in sequence 9 [M(Gi)-G-P].

Cropping sequence 8 (Gm-Ra-Rb) recorded the highest uptake in both 2nd and 3rd years of cropping while sequence 4 exhibited the lowest uptake both in 2nd as well as in 3rd year of cropping. Sequences 7, 1, 3 recorded relatively lower amount of arsenic uptake in all the three years of cropping.

Uptake was higher in sequences where summer rice was a component crop while slightly lower values were obtained in sequences having elephant-foot yam. So, it became quite clear that summer rice played some role towards arsenic contamination as it not only recorded higher content of arsenic in different plant parts resulting in higher uptake but also had the highest water requirement.

**4.7.3.2 Total arsenic uptake by different systems of cropping**

Wide variation was noted among the different systems of cropping in relation to the total arsenic uptake (Table 4.121; Fig. 31). In otherwords, cropping had significant effect on total arsenic uptake by different systems in each of the three years of experimentation.

In 1st year, the maximum arsenic uptake (176.21 g $ha^{-1}$) was seen with sequence 5 which was significantly higher than the others while sequence 8, 9 and 1 had taken up more or less similar amount. Minimum uptake (66.48 g $ha^{-1}$) was noted with sequence 7 in that year.

In 2nd year too, the maximum uptake (191.35 g $ha^{-1}$) was noted in sequence 5 followed by sequence 8 (161.90 g $ha^{-1}$). Comparatively lower amount of uptake was noted in sequences 2, 4, 9 and 10 with sequence 3 having the lowest uptake (89.44 g $ha^{-1}$).

Sequence 4 had the maximum uptake (188.76 g $ha^{-1}$) in 3rd year followed by sequence 5 (184.58 g $ha^{-1}$) while minimum uptake (94.80 g $ha^{-1}$) was noted in sequence 3. Sequences 2 and 6 recorded slightly lower uptake than sequence 4 in that year.

Sequences having summer rice, *viz,* 5 and 8 recorded greater amount of uptake during all the three years of cropping owing to high arsenic content in different plant

## TABLE 4.120

**Arsenic uptake through consumable economic products of crops in different systems of cropping**

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 37.55 | 30.57 | 28.62 |
| 2. E-M-G | 39.94 | 45.87 | 58.27 |
| 3. E-Md-S | 23.15 | 43.25 | 45.01 |
| 4. Jo-G-P-S | 18.04 | 21.57 | 21.98 |
| 5. Jo-Ra-Rb | 52.45 | 68.52 | 65.60 |
| 6. E-W-Gn | 46.63 | 46.93 | 56.45 |
| 7. G-Ra-Md | 16.94 | 30.62 | 35.45 |
| 8. Gm-Ra-Rb | 51.17 | 70.34 | 67.87 |
| 9. M(Gi)-G-P | 57.54 | 33.28 | 31.43 |
| 10. E(Ci)-M-G | 33.15 | 44.23 | 57.20 |
| SEm (±) | 0.557 | 0.605 | 2.292 |
| CD at 5% | 1.65 | 1.79 | 6.80 |

## TABLE 4.121

**Total arsenic uptake by different systems of cropping**

| Cropping sequence | Arsenic uptake (g $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 115.78 | 114.86 | 106.40 |
| 2. E-M-G | 95.88 | 131.67 | 131.50 |
| 3. E-Md-S | 70.94 | 89.44 | 94.80 |
| 4. Jo-G-P-S | 110.99 | 119.11 | 188.76 |
| 5. Jo-Ra-Rb | 176.21 | 191.35 | 184.58 |
| 6. E-W-Gn | 88.69 | 103.05 | 124.16 |
| 7. G-Ra-Md | 66.48 | 103.11 | 114.92 |
| 8. Gm-Ra-Rb | 121.40 | 161.90 | 122.50 |
| 9. M(Gi)-G-P | 121.42 | 135.75 | 97.70 |
| 10. E(Ci)-M-G | 86.21 | 124.41 | 132.11 |
| SEm (±) | 4.17 | 10.23 | 5.13 |
| CD at 5% | 12.38 | 30.38 | 15.42 |

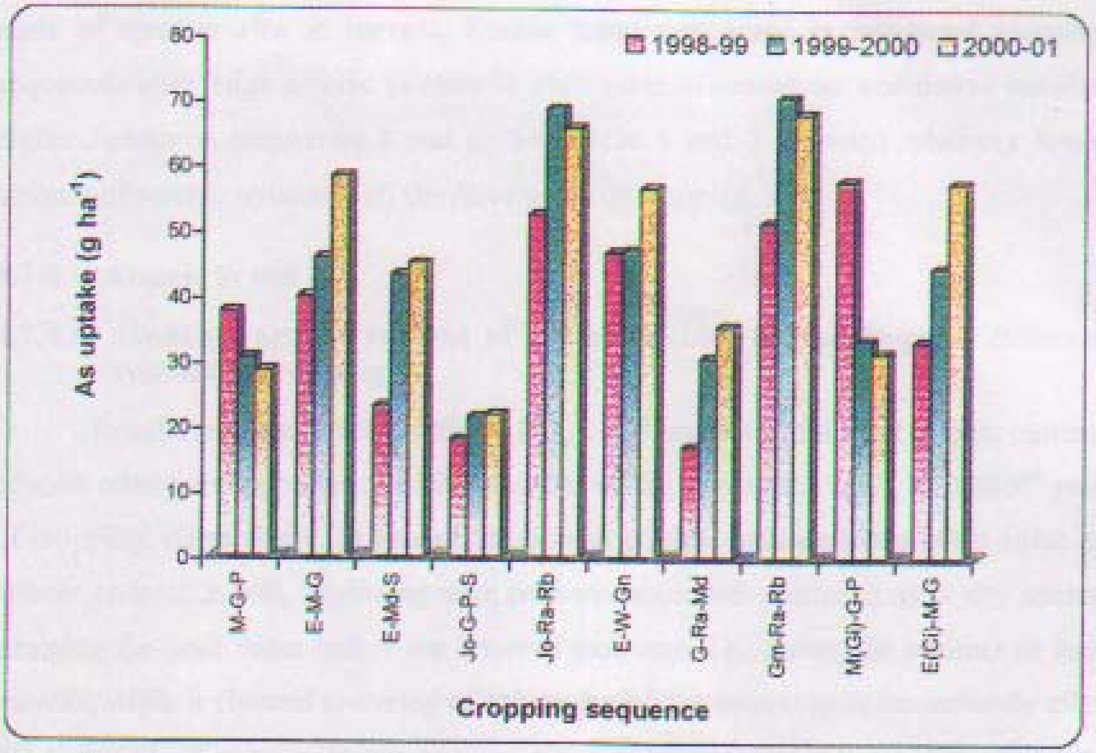



**Fig. 30 : Arsenic uptake through consumable/economic products of crops in different systems of cropping**

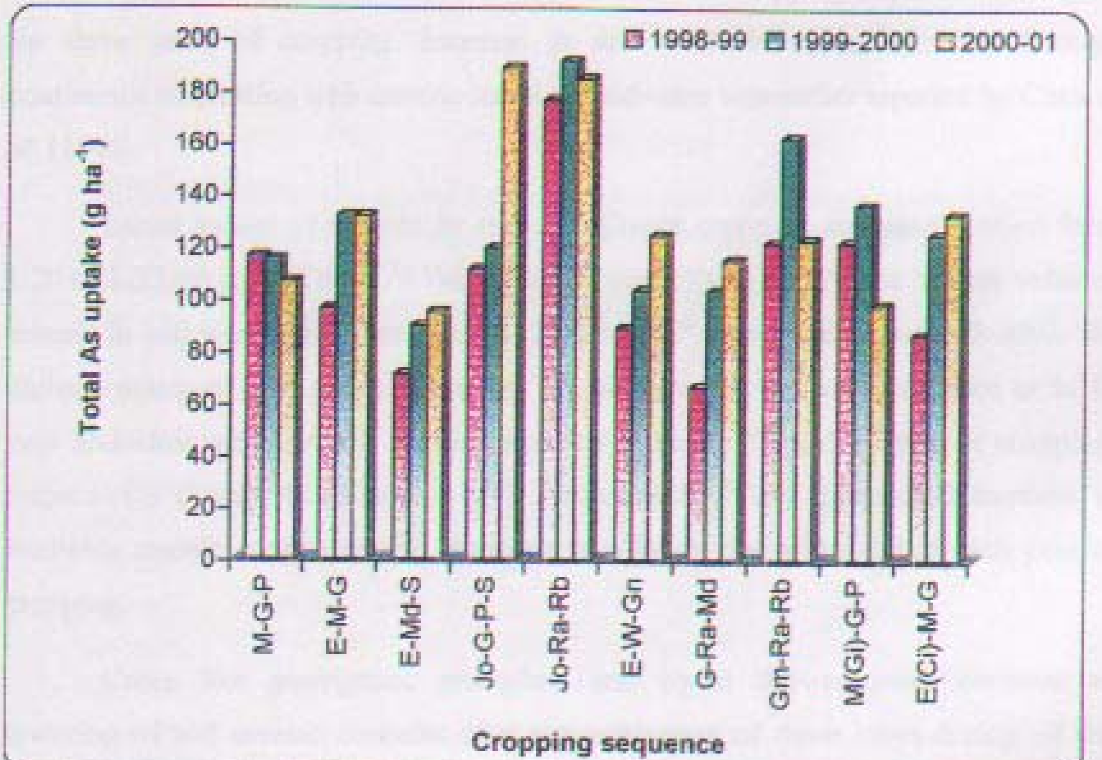



**Fig. 31 : Total arsenic uptake by the different systems of cropping**

parts of summer rice at harvest. Similar trend was noted in jute-based cropping sequences also. High arsenic content in plant parts of greengram and potato resulted higher uptake in sequences 1 and 2. Sequences 3 and 7 recorded relatively lower amount of arsenic uptake in all the three years of cropping.

### 4.7.4 Arsenic in soil

#### 4.7.4.1 Available arsenic content of soil as affected by the crops in different systems of cropping

Results summarised in Tables 4.122, 4.123 and 4.124 revealed arsenic content of soils after growing crops one after another within a sequence in $1^{st}$, $2^{nd}$ and $3^{rd}$ year of cropping, respectively. In general, it showed gradual increase towards the value of arsenic content in soil, beginning with post-monsoon and continued up to dry season attaining the peak value before the onset of monsoon, *i.e.,* during the summer or lean months, while it showed lowering of values during the monsoon or immediately after the cessation of rains with the various crops in different sequences. Though some decline in soil arsenic contents were found during the period of monsoon, nevertheless, it did not increase uniformly in different cropping sequences during all the three years of cropping. Increase in soil available arsenic contents through continuous cultivation with arsenic laden groundwater was earlier reported by Chan *et al.* (1992).

Initial values of arsenic in soil of different cropping sequences varied from 1.20 to 1.37 mg $kg^{-1}$ of soil. At the end of $1^{st}$ year (Table 4.122), the highest value of arsenic in soil was found after sesame (2.00 mg $kg^{-1}$ of soil) in sequence 3 while the highest values of 2.14 and 2.63 mg $kg^{-1}$ of soil were on the same sequence as in $1^{st}$ year and after summer/*boro* rice in sequence 5 during $2^{nd}$ and $3^{rd}$ year of cropping, respectively (Table 4.123 and 4.124). Sequence 6, 7 and 2 recorded increase in available arsenic content of soil relatively at a lower rate at the end of each year of cropping.

Crops like greengram, groundnut and wheat showed some decrease or lowering of soil arsenic contents after the cultivation of those crops during all the three years of cropping. Growing and incorporation of green manure *in situ* before wet season rice in sequence 8 resulted decrease in soil available arsenic content during all the three years of cropping. While crops like maize, potato, elephant-foot

## TABLE 4.122

**Effect of different systems of cropping on Olsen-extractable ($NaHCO_3$-extractable) arsenic (available) content of soil in 1998-1999**

| Cropping sequence | Olsen-extractable As content (mg $kg^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 1.20 | 1.53 | 1.39 | 1.60 | |
| 2. E-M-G | 1.30 | 1.80 | 2.07 | 1.70 | |
| 3. E-Md-S | 1.37 | 1.70 | 1.90 | 2.00 | |
| 4. Jo-G-P-S | 1.24 | 1.44 | 1.43 | 1.40 | 1.47 |
| 5. Jo-Ra-Rb | 1.29 | 1.43 | 1.40 | 1.66 | |
| 6. E-W-Gn | 1.23 | 1.59 | 1.10 | 1.24 | |
| 7. G-Ra-Md | 1.22 | 1.10 | 1.20 | 1.34 | |
| 8. Gm-Ra-Rb | 1.23 | 1.12 | 1.00 | 1.43 | |
| 9. M(Gi)-G-P | 1.28 | 1.61 | 1.45 | 1.64 | |
| 10. E(Ci)-M-G | 1.35 | 1.89 | 2.10 | 1.70 | |
| SEm (±) | 0.032 | 0.043 | 0.034 | 0.066 | |
| CD at 5% | 0.09 | 0.127 | 0.10 | 0.19 | |

## TABLE 4.123

**Effect of different systems of cropping on Olsen-extractable ($NaHCO_3$-extractable) arsenic (available) content of soil in 1999-2000**

| Cropping sequence | Olsen-extractable As content (mg $kg^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 1.56 | 1.68 | 1.54 | 1.80 | |
| 2. E-M-G | 1.64 | 2.20 | 1.69 | 1.30 | |
| 3. E-Md-S | 2.00 | 1.90 | 2.00 | 2.14 | |
| 4. Jo-G-P-S | 1.47 | 1.62 | 1.50 | 1.41 | 1.52 |
| 5. Jo-Ra-Rb | 1.66 | 1.54 | 1.72 | 1.86 | |
| 6. E-W-Gn | 1.20 | 1.34 | 1.16 | 1.10 | |
| 7. G-Ra-Md | 1.23 | 1.30 | 1.40 | 1.48 | |
| 8. Gm-Ra-Rb | 1.36 | 1.12 | 1.10 | 1.70 | |
| 9. M(Gi)-G-P | 1.61 | 1.78 | 1.64 | 1.86 | |
| 10. E(Ci)-M-G | 1.70 | 2.26 | 1.74 | 1.34 | |
| SEm (±) | | 0.112 | 0.055 | 0.054 | |
| CD at 5% | | 0.33 | 0.16 | 0.16 | |

## TABLE 4.124

**Effect of different systems of cropping on Olsen-extractable ($NaHCO_3$-extractable) arsenic (available) content of soil in 2000-2001**

| Cropping sequence | Olsen-extractable As content (mg $kg^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Initial | After 1st crop | After 2nd crop | After 3rd crop | After 4th crop |
| 1. M-G-P | 1.80 | 2.36 | 2.00 | 2.20 | |
| 2. E-M-G | 1.30 | 3.53 | 1.66 | 2.30 | |
| 3. E-Md-S | 2.10 | 2.21 | 2.42 | 2.60 | |
| 4. Jo-G-P-S | 1.60 | 1.64 | 1.40 | 1.76 | 1.69 |
| 5. Jo-Ra-Rb | 1.86 | 1.92 | 1.96 | 2.63 | |
| 6. E-W-Gn | 1.09 | 2.00 | 2.42 | 2.10 | |
| 7. G-Ra-Md | 1.48 | 1.46 | 1.62 | 2.18 | |
| 8. Gm-Ra-Rb | 1.72 | 1.64 | 1.92 | 2.42 | |
| 9. M(Gi)-G-P | 1.68 | 2.26 | 2.10 | 2.26 | |
| 10. E(Ci)-M-G | 1.32 | 3.36 | 1.60 | 2.34 | |
| SEm (±) | | 0.277 | 0.103 | 0.030 | |
| CD at 5% | | 0.82 | 0.30 | 0.09 | |

## TABLE 4.125

**Effect of different systems of cropping on Olsen-extractable ($NaHCO_3$-extractable) arsenic (available) content of soil over the years**

| Cropping sequence | Olsen-extractable As content (mg $kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | | 1999-2000 | | 2000-2001 | |
| | Initial | Final | Initial | Final | Initial | Final |
| 1. M-G-P | 1.20 | 1.60 | 1.56 | 1.80 | 1.80 | 2.20 |
| 2. E-M-G | 1.30 | 1.70 | 1.64 | 1.30 | 1.30 | 2.30 |
| 3. E-Md-S | 1.37 | 2.00 | 2.00 | 2.14 | 2.10 | 2.60 |
| 4. Jo-G-P-S | 1.24 | 1.47 | 1.47 | 1.52 | 1.60 | 1.69 |
| 5. Jo-Ra-Rb | 1.29 | 1.66 | 1.66 | 1.86 | 1.86 | 2.63 |
| 6. E-W-Gn | 1.23 | 1.24 | 1.20 | 1.10 | 1.09 | 2.10 |
| 7. G-Ra-Md | 1.22 | 1.34 | 1.23 | 1.48 | 1.48 | 2.18 |
| 8. Gm-Ra-Rb | 1.23 | 1.43 | 1.36 | 1.70 | 1.72 | 2.42 |
| 9. M(Gi)-G-P | 1.28 | 1.64 | 1.61 | 1.86 | 1.68 | 2.26 |
| 10. E(Ci)-M-G | 1.35 | 1.70 | 1.70 | 1.34 | 1.32 | 2.34 |
| SEm (±) | 0.032 | 0.066 | | 0.054 | | 0.030 |
| CD at 5% | 0.09 | 0.19 | | 0.16 | | 0.09 |

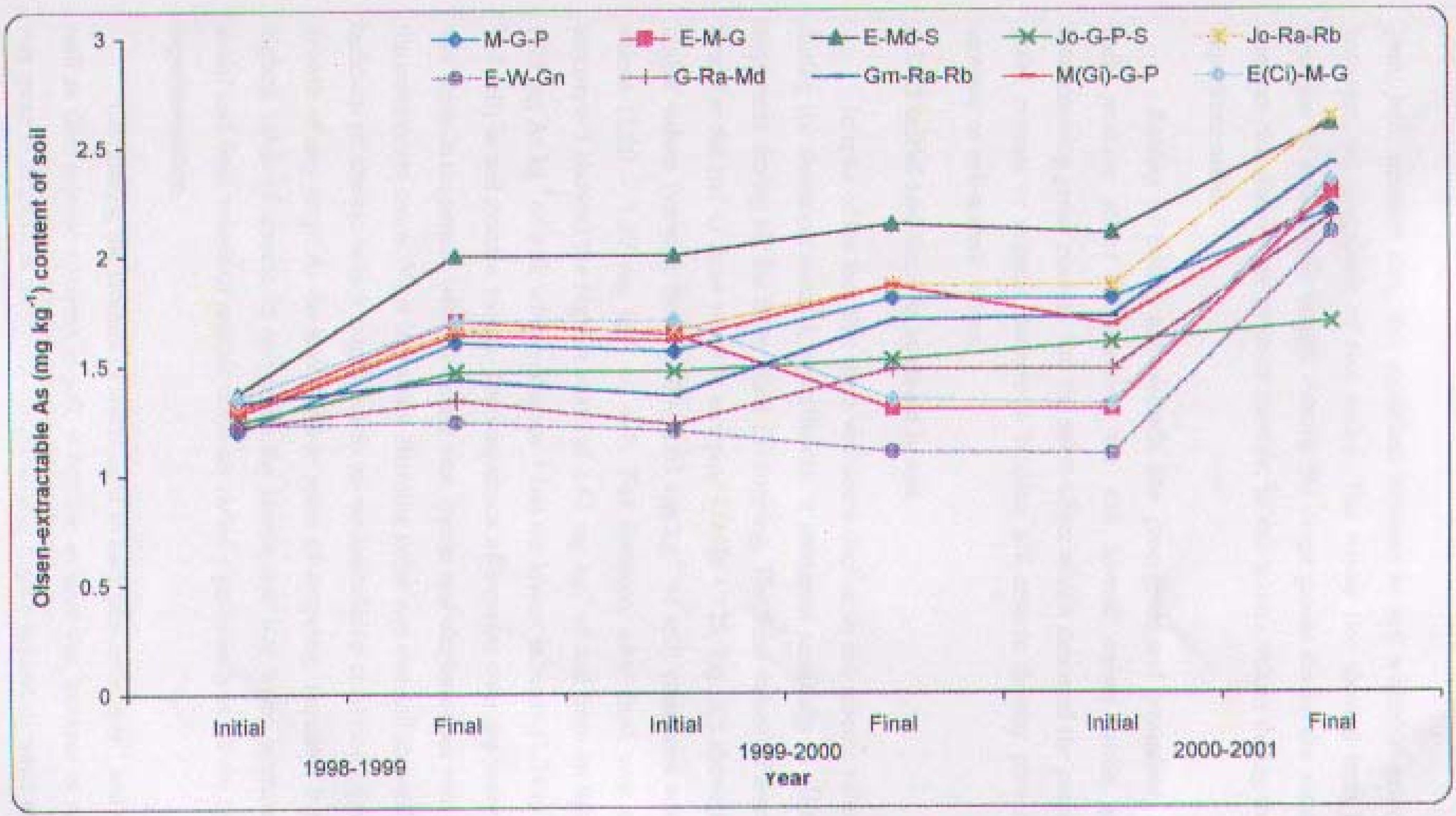



**Fig. 32 : Variation in Olsen-extractable (available) arsenic (As) content of soil in different systems of cropping**

yam, jute, summer rice, etc. exhibited increase in soil available arsenic contents, however, the magnitude of rise varied. The winter rice showed both increase and decrease of soil arsenic values. Among the crops grown during the summer months, summer rice showed the greatest increase in soil arsenic values during the 3rd year of experimentation.

Raising of pulses and oilseeds like greengram and groundnut, etc. showed their positive effect in lowering the soil arsenic values while growing and incorporating green manure had the same effect which indicated the positive effect of green manure or organic manure in binding soil arsenic thereby preventing further increase of soil arsenic values.

**4.7.4.2 Initial and final As contents in soil**

In spite of the fact that there was some decline in soil arsenic values especially during the monsoon months, nevertheless, it increased unequally in all the cropping sequences during all the three years of cropping. The final values of arsenic contents in soil at the end of three years of cropping (Table 4.125; Fig. 32) showed sufficiently higher values (varying from 2.10 – 2.63 mg $kg^{-1}$ of soil) compared with the initial values (1.20 – 1.37 mg $kg^{-1}$ of soil). For instance, after final year of cropping, sequence 5 showed the highest value of 2.63 mg $kg^{-1}$ of soil from an initial status of 1.29 mg As $kg^{-1}$ of soil; while sequence 4 had the lowest increase (1.24 to 1.69 mg $kg^{-1}$ of soil) in soil arsenic values. The magnitude of increase over the years of cropping was more in sequences where summer rice, maize and elephant-foot yam were one of the component crops. Most important alarming point was that soil showed progressive build-up of arsenic which might led to an uncontrollable condition of soil unfit for growth of any crop. At the end of three years of cropping, sequence 5 recorded the highest value of arsenic in soil while the lowest one was noted in sequence 6. The initial and final values of arsenic contents varied significantly in all the three years of experimentation.

Comparing the amount of water used in each sequence $year^{-1}$ and the initial as well as final arsenic contents in soil, it became evident that increase in As build-up was more in sequences receiving comparatively higher volume of water especially for crops grown during the summer months, like *boro* rice, elephant-foot yam, etc.

# Chapter 5

# SUMMARY AND CONCLUSION

# 5. SUMMARY AND CONCLUSION

The widespread arsenic contamination of groundwater exceeding the maximum acceptable concentration (0.05 mg As $l^{-1}$ of water) has been detected over 68 blocks in 9 districts of West Bengal. An investigation was undertaken in the arsenic affected areas of Gotera Mouza, Chakdah in Nadia District of West Bengal for 3 consecutive years (from March 1998 to June 2001) comprising different systems of cropping with crops having low water demand, besides being remunerative, with the objectives to find out the yield performances of various crops under different systems of cropping *vis-à-vis* their economics; to study the build-up or uptake of arsenic in different plant parts of the crops including the consumable portions at different stages; uptake of N, P and K by the component crops as well as by the sequences; the change in N, P, K and available arsenic contents of soil after growing each crop, each sequence and at the end so as to find out some alternative and suitable cropping sequences to replace the traditional winter rice – summer rice sequence.

Altogether ten different systems of cropping were followed in a ramdomised block design with 3 replications. The salient findings are summarized below:

No visual phytotoxic effect of arsenic was observed on any of the crop plants at any stage and plant growth remained unaffected.

Various plant growth attributes like LAI, DM accumulation and CGR of crops were found as normal. Growing crops in different systems of cropping resulted variations in LAI of potato, rice and maize whereas no significant variation was noted in case of jute, mustard and sesame while greengram and elephant-foot yam exhibited contrasting effects at some stages of growth. Both groundnut and wheat, grown in sequences, showed no abnormality towards LAI at various stages of growth.

Growing greengram after jute in sequence 4 resulted in higher values of LAI while intercropped greengram (with maize) had lower LAI. LAI of summer maize was found to be higher than maize grown in winter. Growing and incorporating green manure resulted in higher LAI of the succeeding crops of both winter and summer rices.

The accumulation of DM was influenced due to the practice of growing crops in different systems of cropping in case of greengram, potato, maize, rice and elephant-foot yam. Crops like jute, mustard and sesame in sequences did not show any significant variation at any stage of crop growth. DM accumulation of groundnut and wheat showed an increasing trend upto 75 DAS. Growing greengram after jute showed higher DM accumulation at all the stages; no such definite trend became evident in case of potato. Summer maize resulted higher DM accumulation than winter maize in various sequences. Both winter and summer rices, grown after green manuring in succession, gave higher DM at all the stages. Jute after summer rice and sesame after potato recorded higher DM in most of the stages. Though significant variation towards DM accumulation of elephant-foot yam was noted among the sequences, yet any single sequence did not show any superiority.

CGR was influenced in crops like greengram, potato, rice, maize and elephant-foot yam grown in different sequences while no such variation in CGR was observed on jute, mustard, potato and sesame. Very low CGR was observed in intercropped greengram. CGR of summer rice in sequences was found to be higher than winter rices at most of the stages of crop growth. Jute when succeeded summer rice showed higher CGR value than when grown after sesame.

No abnormality in root growth of the crops was noted during any stage of crop growth throughout the entire period of experimentation. No root discolouration and wilting, typical of arsenic poisoning, were noted on any of the crops. All the crops grown in different systems of cropping did not result in any significant variation in root volume and dry weight at any stage except rice.

Number of effective nodules plant$^{-1}$ of groundnut was found to be highest compared with greengram and green manure (dhaincha). Dry weight of nodule plant$^{-1}$ (g) was found to be highest at 45 DAS in greengram and at 75 DAS in groundnut while with the practice of various systems of cropping did not have any impact either on nodule number or on nodule dry weight plant$^{-1}$.

Yield of all the crops was recorded to be normal and no ill effect of arsenic was observed. Comparatively poor yields of greengram were noted in 2nd year and it recorded the highest seed yields after potato while intercropped one recorded the lowest yields. Stover yield was found to vary in first two years while it showed no variation in the last year.

Gradual increase in tuber yield of potato was observed over the years with significant variation among the sequences only in first year. Haulm yield of potato showed variation in all the years of investigation. Both grain and straw yields of rice varied resulting from different systems of cropping. Summer rice recorded higher yields than winter rice. Growing and incorporating green manure influenced higher yield of following winter and summer rices. Maize in sequence 1 gave the highest yields. Jute, sesame and mustard in different sequences recorded little variation with gradual increase in yield over the years. Corresponding stick, stover and straw yields also did not record any variation. Groundnut and wheat showed gradual progress in yield over the years. Corm yield of elephant-foot yam was found to be influenced with the progress in yield over the years. Harvest indices of all the crops did not record much variation among the sequences.

Uptake of N, P and K were observed to vary in case of greengram, rice, maize and elephant-foot yam which were raised with different sequences while the reversed was seen with regard to jute, mustard and sesame. In case of potato, N and K uptake showed variation out of the sequences.

Sequences having maize and elephant-foot yam showed higher uptake of both N and K. Nitrogen uptake was highest in sequence 9 in 1st year and in sequence 10 in other years. Sequence 5, 6 and 10 recorded higher P uptake with the highest uptake in sequence 6. Relatively higher K uptake was noted in sequences 3, 6 and 10.

Soil nutrient status in relation to total N and available P improved a lot at the end of 3rd year as compared to their initial values in most systems of cropping. Available K content of soils decreased in most sequences at the end.

Higher gross and net returns were obtained in sequences having elephant-foot yam or maize as a component crop. Gross as well as net returns obtained from two jute-based sequences recorded little variation. In 1st year, sequence 6 accrued the highest gross and net returns (Rs 1,38,770 and Rs 67,706, respectively) followed by sequences like 10, 9, 3, etc. Sequences 3 and 6 showed the highest gross return in other two years while sequence 3 recorded the highest net return in those years. Most of the sequences resulted in higher gross and net returns as compared to the traditional rice-rice sequence (8).

Benefit : cost ratio obtained during the last two years of cropping was found to be higher in most of the sequences tried compared with the traditional one (sequence 8). The highest benefit : cost ratios of 1.80 : 1, 2.13 : 1 and 2.14 : 1 were obtained in sequence 9 in 1st year and in sequence 7 during both 2nd and 3rd year of cropping, respectively.

By and large, arsenic uptake or build-up in different plant parts of the crops showed progressive decline from roots, stem, leaves and in economic produces with most of the crops tried. Crops showed progressive build-up of arsenic with the progress of growth in different plant parts. Mustard, groundnut and sesame recorded less uptake of arsenic in plant parts while elephant-foot yam and potato showed moderate values. Among the cereals: summer rice in various sequences recorded very high values of arsenic build-up in all the plant parts. Wheat root recorded very high values of arsenic while maize roots showed comparatively lower values. Arsenic content in summer rice grain varied from 7.84 – 10.00 mg $kg^{-1}$ at harvest during the course of investigation while the same in winter rice showed values ranging from 3.90 – 6.80 mg $kg^{-1}$. Among the crops grown during the lean period comprising summer months, summer rice always exhibited the highest content of arsenic in plant parts. Though roots exhibited very high values of arsenic build-up, however, in case of potato and elephant-foot yam, the economic produces in spite of being underground, recorded comparatively less build-up. The most alarming point noted was that crops showed progressive increase towards build-up of arsenic over the years of experimentation.

Crops like greengram, rice, maize and elephant-foot yam showed variation in arsenic uptake by them among the sequences while in others no such effect was noted. In case of potato, variation in total arsenic uptake was noted during 1st and 3rd years of experimentation. Summer rice recorded the highest uptake (74.13 – 77.65 g $ha^{-1}$) among the crops tried; maize, jute, elephant-foot yam gave moderate uptake while groundnut and sesame resulted in lower uptake. Sesame grown in different systems of cropping recorded the lowest value of total arsenic uptake among all the crops.

Arsenic uptake via the economic produces of crops (consumable) in a sequence showed significant variation among the sequences. Sequences having either summer rice or maize resulted in higher uptake. Sequence 9 gave the highest uptake (57.54 g As $ha^{-1}$) in 1st year while sequence 8 having both winter and summer rices exhibited the highest uptake in later two years. Two jute-based sequences resulted variation in arsenic uptake through economic produces with higher uptake in sequence 5 having both the rices as compared to sequence 4.

Sequences having maize, jute and rice (both winter and summer) gave very high values of arsenic uptake. Relatively less uptake was noticed in sequences 2, 3 and 7; on the contrary, sequence 8, 5, 1 and 9 etc. gave very high amount of arsenic uptake.

Soils showed progressive build-up of arsenic (available) with continued cultivation using irrigation water loaded with arsenic; it showed increasing trend gradually beginning with post-monsoon to *rabi* and attaining the peak value before monsoon, *i.e.*, during the summer months, while it showed declining trend during the monsoon or just after the final withdrawal of monsoon in different sequences of cropping.

Available arsenic content of soils after each year of cropping was found to vary among the sequences. Though some decline in soil arsenic values were noted during the monsoon months, yet it increased in varying magnitudes at the end of each year of cropping. At the end of 3rd year of cropping, sequence 5 gave the highest value (2.63 mg As $kg^{-1}$ of soil) among all the sequences tried. Crops like greengram, groundnut, wheat, etc. recorded lowering in soil available arsenic contents after their cultivation while summer rice, maize, elephant-foot yam, potato, etc. caused increase in arsenic content of soils after harvest of those crops in varying magnitudes. Winter rice crop showed both increase and decrease of soil available arsenic contents. Growing and incorporating green manure resulted in lower degree of increase in soil available arsenic contents by the succeeding rice crops in sequence 8.

The results summarized above led to the following conclusions:

i) Arsenic was accumulated in plants grown on arsenic contaminated soils.

ii) Crops showed specificity with regard to accumulation or build-up of arsenic in various plant parts.

iii) Levels of soil available arsenic content showed gradual increase, yet it did not produce any visual phytotoxic effect; plant growth as well as root growth did not exhibit any abnormality at those levels.

iv) Continued cultivation with some crops resulted in improvement of soil fertility with respect to N and P contents in most of the sequences while K content showed lowering in some of the sequences.

v) Available arsenic content of soil increased to a greater proportion where summer rice was raised; besides, huge amount of arsenic was taken up by the grains of summer rice. More or less similar trend was noticed in case of maize.

vi) Crops like wheat, groundnut, greengram showed some lowering of soil available arsenic contents through their cultivation. This was especially important in connection with suitability of those crops in sequence in place of summer rice covering the pre-monsoon summer months. Low arsenic uptake by those crops complimented to the advantage of their suitability in sequences.

vii) Cultivation of pulses, addition or incorporation of green manure demonstrated their positive effect towards moderating the arsenic build-up in soil as well as in various plant parts of crops raised thereafter in varying proportions.

viii) Gross return and corresponding benefit : cost ratio accrued were higher in most of the sequences than the traditional rice-rice system (sequence 8 in the experiment). Different elephant-foot yam - based sequences, namely, 2, 3, 6 and 10 recorded higher returns alongwith high benefit : cost ratio. From benefit : cost ratios obtained, it became evident that much practised rice-rice system could easily be substituted by sequence 3 (elephant-foot yam – mustard – sesame), sequence 2 (elephant-foot yam – maize – greengram) or sequence 7 (greengram - rice - mustard).

ix) Comparing the volume of water given to different sequences, some crop sequences requiring less quantity of water throughout the year, compared with the traditional rice-rice system, appeared to be economically viable. Greengram - rice (winter) – mustard (sequence 7) was charcterised by the lowest volume of water need throughout the year, but the benefit : cost ratio was higher when compared with the volume of water applied to the different sequences through irrigation *vis-à-vis* their corresponding benefit : cost ratios. The same was also true for sequence 3. In case of rice-rice sequence (number 8), although the benefit : cost ratio was higher, yet the volume of water used was also the highest. The amount of total arsenic uptake was also very high in sequence 8 (rice-rice) as compared to the same in sequence 2, 3 or 7.

Thus, considering the points of total arsenic uptake, net return and corresponding benefit : cost ratio as well as the amount of water used for each sequence, the much talked about rice-rice system, mainly responsible for arsenic mobilistion in groundwater in Bengal basin, can easily be substituted by sequences like elephant-foot yam – maize – greengram, elephant–foot yam – mustard – sesame or greengram – rice (winter) – mustard. to reduce further spread of arsenic contamination.

# Chapter 6

# FUTURE SCOPE OF RESEARCH

# 6. FUTURE SCOPE OF RESEARCH

India has made rapid stride in agriculture following the 'Green Revolution' during late sixties that prompted the use of HYVs of crops, pesticides, inorganic fertilizer and exploitation of groundwater reserve. The latter, on it's way, has brought along numerous soil and water related problems. The widespread arsenic contamination in West Bengal is being thought to have originated from the heavy withdrawal of groundwater especially during the lean months (summer months) of the year. The present situation is alarming, painstaking as well as ever increasing. Though some research work has been conducted and going on centering around the impact of arsenic on soil as well as on the quality of drinking water, surprisingly till date, very little attention on research has been paid towards various aspects of the crops grown on arsenic contaminated soils raised with arsenic contaminated irrigation water (groundwater source); or in other words, how the toxin (arsenic) is entering into the food chain, via water and soil to the crops, and ultimately to human. Till now, the major hypothesis relates arsenic contamination in groundwater in West Bengal to over-exploitation of groundwater to provide irrigation for *boro*/summer rice. From the present study, it became clear that the pressure or load on groundwater withdrawal for irrigation must be reduced particularly during the pre-monsoon months. Therefore, attempt is to be taken to replace *boro*/summer *rice* by other crops such as food, fodder, pulses, oilseeds, vegetables, etc. either as sole or as intercropping systems covering the summer months (January –April/May).

Investigation can also be undertaken further in the following directions in order to reduce the degree and further spread of such a grave natural calamity.

- Frequency and appropriate method of scheduling irrigation to crops should be worked out so as reduce the load on groundwater withdrawal to prevent further spread of the menace particularly on crops raised during summer.

- Role of organic manures including different green manures and crop residues in relation to movement and build-up of arsenic in soil as well as in plants should be investigated. In this regard, the role of soil organic matter to bind soil-arsenic and the effect thereupon on succeeding crops, particularly on rice, should thoroughly be investigated.

- Proper identification of suitable varieties of crops towards uptake of less arsenic on the edible portion calls for future study.

- Working out of the appropriate form, dose and time of application of nutrients through inorganic fertilizer especially with reference to 'P' and 'K' must be undertaken.

- Investigation can also be undertaken for a prolonged period to obtain results that could help in minimising the problem by way of cropping, use of biofertilizers, etc.

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* Original not seen

# APPENDICES

# APPENDICES

## APPENDIX 1

### TABLE A(i)

**Survey report of arsenic affected seven districts, upto January, 1996**

| | |
|---|---|
| Total area | 37,493 $km^2$ |
| Total population | 3,46,32,024 |
| Total number of blocks/PS | 162 |
| Total number of arsenic affected blocks/PS | 50 |
| Total population of arsenic affected blocks | 95,62,898 |
| Approx. population drinking arsenic-contaminated water above 0.05 mg $l^{-1}$ | >11,00,000 |
| Approx. population drinking arsenic-contaminated water above recommended value (0.01 mg $l^{-1}$) | >15,00,000 |
| Approx. population showing arsenic-related skin manifestation on their body | > 2,20,000 |

Source: Mandal *et al.* 1996.

### TABLE A(ii)

**Survey report of arsenic affected districts, blocks, villages in West Bengal (from January 1990 to January 1996)**

| Year | Districts | Blocks | Total number of villages |
|---|---|---|---|
| 1990 | South 24-Parganas | Ranipur | 7 |
| | Murshidabad | Raninagar-II, Domkal | |
| 1993 | South 24-Parganas | Bhangor-I | 330 |
| | North 24-Parganas | Barasat-1, Barasat-II, Habra-I, II, Deganga, Swarupnagar, Basirhat, Baduria, Gaighata | |
| | Nadia | Haringhata, Chakdaha, Santipur, Nabwadip, Kaliganj, Tehatta-I, II, Karimpur-I, II | |
| | Burdwan | Purbasthali-I, Purbasthali-II | |
| | Murshidabad | Beldanga, Baharampur, Nowda, Hariharpara, Raninagar-1, Jalangi, Suti-II | |
| | Malda | Kaliachalk-I, Kaliachalk-II, Kaliachalk-III, Englishbazar, Manikchalk | |
| May 1994 | South 24-Parganas | Sonrpur | 13 |
| August 1995 | South 24-Parganas | Joynagar, Magrahat-II | |
| | Murshidabad | Suti-I, Farakka, Bhagabangola-II, Murshidabad, Raghunathjung-II | 116 |
| January 1996 | South 24-Parganas | Bhangor-II, Budge Budge-I, II, Bishnupur-I, Bishnupur-II | 94 |
| | Hooghli | Balagarh | |
| Total | Seven districts | Fifty blocks | 560 |

Source: Mandal *et al.* (1996)

## TABLE A(iii)

**Arsenic concentration in groundwater and arsenic content in hair, nail, urine and skin-scale of people drinking arsenic-contaminated water above 0.05 mg $l^{-1}$**

| Concentration of total arsenic in water samples (mg $l^{-1}$) | | | | | Concentration of arsenic in urine samples* (mg $l^{-1}$) | | Concentration of arsenic in hair samples** (mg $kg^{-1}$) | | Concentration of arsenic in nail samples*** (mg $kg^{-1}$) | | Concentration of arsenic in skin scale samples (mg $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Above recommended value to maximum permissible limit | | Above maximum permissible limit | | | | | | | | | |
| Safe | Range | Average | Range | Average | Range | Average | Range | Average | Range | Average | Range | Average |
| <0.01 | 0.01-0.049 | 0.205 | 0.05-3.7 | 0.220 | 0.03-4.58 | 0.865 | 1.00-42.15 | 8.44 | 1.10-57.69 | 15.25 | 0.8-17.75 | 8.66 |
| (n = 7548) | (n = 3405) | | (n = 8754) | | (n = 1166) | | (n = 671) | | (n = 900) | | (n = 150) | |

n = Number of samples analysed

* = Normal excretion levels of arsenic in urine range from 0.005 to 0.040 mg $d^{-1}$

** = Normal amount of arsenic in hair is about 0.08 to 0.25 mg $kg^{-1}$ with 1.0 mg $kg^{-1}$ being indication of presence of excess arsenic

*** = Normal arsenic content of soils 0.43 – 1.08 mg $kg^{-1}$

Source: Mandal *et al.* (1996)

**APPENDIX 2**

**TABLE 4(i)**

**Dry matter of jute at harvest**

| Cropping sequence | Total dry matter at harvest (t $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 4. Jo-G-P-S | 10.68 | 11.58 | 15.28 |
| 5. Jo-Ra-Rb | 11.17 | 11.23 | 16.60 |

**TABLE 4(ii)**

**Biomass production of green manure at harvest**

| Cropping sequence | Biomass at harvest (t $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 8. Gm-Ra-Rb | 2.4 | 3.1 | 4.2 |

**TABLE 4(iii)**

**Biomass production of cowpea at harvest**

| Cropping sequence | Biomass at harvest (t $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 10. E(Ci)-M-G | 12.3 | 10.1 | 12.7 |

**TABLE 4(iv)**

**Tuber dry weight of potato at harvest**

| Cropping sequence | Dry weight of tuber (t $ha^{-1}$) | | |
|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 |
| 1. M-G-P | 3.98 | 3.51 | 3.91 |
| 4. Jo-G-P-S | 2.83 | 3.47 | 3.71 |
| 9. M(Gi)-G-P | 3.77 | 3.80 | 3.74 |

**TABLE 4(v)**

**Dry weight of corm and shoot of elephant-foot yam at harvest**

| Cropping sequence | Dry weight of corm (t $ha^{-1}$) | | | Dry weight of shoot (t $ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 1998-1999 | 1999-2000 | 2000-2001 | 1998-1999 | 1999-2000 | 2000-2001 |
| 2. E-M-G | 5.33 | 7.83 | 10.43 | 1.56 | 1.87 | 1.78 |
| 3. E-Md-S | 3.89 | 10.25 | 10.22 | 1.34 | 2.04 | 2.08 |
| 6. E-W-Gn | 6.15 | 6.34 | 8.84 | 1.42 | 1.60 | 1.63 |
| 10. E(Ci)-M-G | 4.90 | 7.68 | 10.48 | 1.53 | 1.94 | 2.01 |

## APPENDIX 3

★ *Cost of cultivation of crops*

➢ **Greengram**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 400 |
| Fertilizer | 888 |
| Human labour (35) | 1400 |
| Irrigation | 100 |
| **Total** | **2,788** |

➢ **Potato**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 13,000 |
| Fertilizer | 3,906 |
| Irrigation | 100 |
| Human labour (150) | 6,000 |
| Bullock labour (30 pair) | 1,800 |
| Plant protection | 1,000 |
| **Total** | **25,806** |

➢ **Rice (a) winter (*aman*)**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 540 |
| Manure | 300 |
| Fertilizer | 1,320 |
| Irrigation | 180 |
| Human labour (160) | 6,400 |
| Bullock labour (60 pair) | 3,600 |
| Plant protection | 800 |
| **Total** | **13,140** |

➢ **Rice (b) summer (*boro*)**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 600 |
| Manure | 300 |
| Fertilizer | 2,784 |
| Irrigation | 720 |
| Human labour (180) | 7,200 |
| Bullock labour (24 pair) | 1,440 |
| Plant protection | 500 |
| **Total** | **13,544** |

- **Maize**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 630 |
| Fertilizer | 2,604 |
| Irrigation | 90 (in *kharif*, 300 in *rabi* |
| Human labour (150) | 6,000 |
| Bullock labour (25 pair) | 1,500 |
| **Total** | **10,824** in *kharif*<br>**11,034** in *rabi* |

- **Jute**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 338 |
| Fertilizer | 1,269 |
| Irrigation | 180 |
| Human labour (200) | 8,000 |
| Bullock labour (25 pair) | 1,500 |
| Plant protection | 1,040 |
| **Total** | **12,327** |

- **Mustard**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 90 |
| Fertilizer | 1,743 |
| Irrigation | 90 |
| Human labour (180) | 3,200 |
| Bullock labour (20 pair) | 1,200 |
| Plant protection | 800 |
| **Total** | **7,123** |

- **Sesame**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 175 |
| Fertilizer | 1,209 |
| Irrigation | 100 |
| Human labour (100) | 4,000 |
| Bullock labour (20 pair) | 1,200 |
| **Total** | **6,684** |

- **Cowpea**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 250 |
| Human labour (25) | 1,000 |
| **Total** | **1,250** |

- **Groundnut**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 2,100 |
| Manure | 300 |
| Irrigation | 180 |
| Fertilizer | 1,104 |
| Human labour (170) | 6,800 |
| Bullock labour (30 pair) | 1,800 |
| **Total** | **12,284** |

- **Wheat**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 1,000 |
| Fertilizer | 2,298 |
| Irrigation | 180 |
| Human labour (120) | 4,800 |
| Bullock labour (20 pair) | 1,200 |
| **Total** | **9,478** |

- **Elephant-foot yam**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 36,000 |
| Fertilizer | 2,490 |
| Irrigation | 270 |
| Human labour (400) | 16,000 |
| Bullock labour (67 pair) | 4,020 |
| **Total** | **58,780** |

- **Green manure**

| Item | Cost (Rs $ha^{-1}$) |
|---|---|
| Seed | 480 |
| Human labour (40) | 1,600 |
| Bullock labour (40) | 2,400 |
| **Total** | **4,480** |