

**INTEGRATED NUTRIENT MANAGEMENT FOR
CASSAVA (*Manihot esculenta* Crantz.)**

By

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M.Sc. (Ag.)**

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DOCTOR OF PHILOSOPHY
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CERTIFICATE

Mr. GUNNA RAMANANDAM has satisfactorily prosecuted the course of research and that the thesis entitled “**INTEGRATED NUTRIENT MANAGEMENT FOR CASSAVA (*Manihot esculenta* Crantz.)**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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Place: Bapatla



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This is to certify that the thesis entitled “**INTEGRATED NUTRIENT MANAGEMENT FOR CASSAVA (*Manihot esculenta* Crantz.)**” submitted in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the **Acharya N. G. Ranga Agricultural University, Hyderabad** is a record of bonafide research work carried out by **Mr. GUNNA RAMANANDAM** under my guidance and supervision. The subject of the thesis has been approved by the student’s Advisory committee.

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



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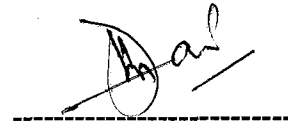
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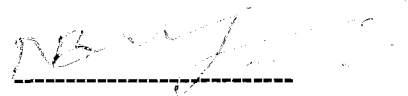
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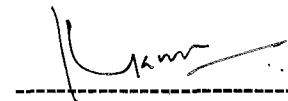
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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	percentage
@	:	at the rate of
^o C	:	degree celsius
Azos	:	<i>Azospirillum</i>
CD(0.05)	:	critical difference at 5% level of significance
cm ²	:	square centimetre
CGR	:	crop growth rate
cm	:	centimetre
DAP	:	days after planting
DAS	:	days after sowing
day ⁻¹	:	per day
<i>et al.</i>	:	and others
Fig.	:	figure
FYM	:	farm yard manure
g ⁻¹	:	per gram
GM	:	green manure
ha	:	hectare
ha ⁻¹	:	per hectare
HCN	:	hydrocyanin
hr	:	hour
K	:	potassium
kg	:	kilogram
K ₂ O	:	potassium oxide
LA	:	leaf area
LAI	:	leaf area index
m	:	metre
m ⁻²	:	per square metre
m ²	:	square metre
MT	:	metric tonnes
µg	:	micro gram
mg	:	milligram
ml	:	milliliter
mm	:	millimetre
N	:	nitrogen
NAR	:	net assimilation rate
P	:	phosphorus
P ₂ O ₅	:	phosphorus pent oxide
RDF	:	recommended dose of fertilizer
Rs/-	:	rupees
S.Em	:	standard error of mean
T	:	treatment
t	:	tonnes
vc	:	vermicompost
viz.	:	namely

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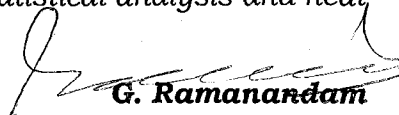
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G. Ramanandam

DECLARATION

I, **GUNNA RAMANANDAM**, hereby declare that the thesis entitled **“INTEGRATED NUTRIENT MANAGEMENT FOR CASSAVA (*Manihot esculenta* Crantz.)”** submitted to the Acharya N.G. Ranga Agricultural University for the degree of **“DOCTOR OF PHILOSOPHY IN HORTICULTURE”** is a result of original research work done by me. It is further declared that the thesis or any part there of has not been published earlier in any manner.

Date: 31, July, 2006
Place: Hyderabad



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ABSTRACT

The present investigation entitled “Integrated nutrient management for cassava (*Manihot esculenta* Crantz)” was undertaken at Agricultural Research Station, Peddapuram, East Godavari district of Andhra Pradesh under rainfed and irrigated conditions during *Kharif* 2002-03 and *Kharif* 2003-04. The studies were carried out with Sree Prakash (S-856) variety of cassava with 13 different INM treatments involving different combinations of recommended, 2/3rd and ½ dose of inorganic fertilizers with organic manures, namely, farm yard manure, vermicompost and *in situ* green manuring with cowpea at 45 DAS and the biofertilizer, *Azospirillum*. Further, the experiments were laid out in a randomized block design with three replications and data on effect of different INM treatments on growth, drymatter production and partitioning, growth analysis parameters, yield, yield attributes, quality and nutrient uptake of cassava were recorded and statistically analyzed. Correlations between yield and yield attributes; and economics of the different treatments were worked out.

The application of organic manures in conjunction with bio-fertilizer and inorganic fertilizers at different levels (T₂ – T₁₃) was in general observed to exert a significant influence on growth attributes, CGR, NAR, drymatter partitioning at harvest, drymatter production at the different growth stages, shoot/root ratio, tuber yield, yield attributes and nutrient uptake under rainfed and irrigated conditions, during the two years of investigation. The different integrated nutrient management treatments studied in the present investigation were also observed to profoundly influence the gross and net returns in addition to benefit: cost ratio of cassava. However, the tuber quality attributes were not significantly influenced by different INM treatments studied.

The application of recommended NPK fertilizer dose along with vermicompost and *Azospirillum* (T₇) had in general resulted in maximum growth attributes, dry matter production, CGR, NAR, yield, yield attributes and nutrient uptake in addition to minimum shoot/root ratio during both the years of investigation under rainfed and irrigated conditions indicating the potential of the INM treatment in enhancing cassava crop yields under both the conditions. The treatment was resulted in maximum gross returns. However, total expenditure was high for the treatment, owing to the high cost of vermicompost resulting in relatively reduced net returns. Further, the application of 2/3rd recommended dose of inorganic fertilizers along with vermicompost and *Azospirillum*

(T8) had resulted in growth attributes, drymatter production, tuber yield, yield attributes and nutrient uptake on par with recommended dose of inorganic fertilizer applied in conjunction with vermicompost and *Azospirillum* (T7) during both years of investigation and under both rainfed and irrigated situations, indicating a scope for realization of higher cassava yields with reduced dose of inorganics resulting in reduced cost of cultivation and maintenance of soil health. The low net returns and benefit : cost ratio in INM treatments with vermicompost component may be enhanced through encouragement of vermicompost production by the farmer himself.

The application of INM treatments involving FYM component (T2-T5) had in general recorded significantly higher yield, compared to application of recommended inorganic fertilizers only (T1) under both rainfed and irrigated conditions during both years of investigation. The application of FYM in combination with *Azospirillum* and different doses of the inorganic fertilizers (T2 - T5) was also observed to in general result in increased total N, P and K nutrient uptake, compared to the application of inorganics alone (T1) under both rainfed and irrigated conditions during both the years of investigation due to an increase in drymatter production, resulting from the improvement in the growth attributes. The net returns were also in general higher with INM treatments involving farm yard due to the relatively high yields coupled with the average cost of the organic component involved corroborating the existing recommendation for use of farmyard manure in conjunction with inorganic fertilizers for increased, economic and sustainable production of cassava under both rainfed and irrigated conditions. Maximum net returns were also recorded in the present investigation for application of 2/3rd dose of recommended inorganics in conjunction with farm yard manure and *Azospirillum* (T3) under both rainfed and irrigated conditions during both the years of investigation.

Application of green manure in conjunction with *Azospirillum* and different levels of inorganic fertilizers (T10 to T13) had in general recorded yield and yield attributes on par with the application of recommended inorganic fertilizers only (T1) under rainfed conditions during both the years of investigation, probably due to unavailability of sufficient nutrients in these treatments under rainfed conditions, resulting from the slow and delayed decomposition of organic material applied under restricted moisture conditions. In contrast, the treatments (T10 to T12) had recorded significantly higher yield and yield attributes, compared to the application of recommended inorganic fertilizers only (T1) under irrigated conditions during both the years of investigation.

The benefit:cost ratio was also in general higher with INM treatments involving green manure component in spite of the relatively low yields, compared to INM treatments involving vermicompost and FYM due to the low cost of green manure, indicating the feasibility of *in situ* green manuring with cowpea in conjunction with inorganic fertilizers and *Azospirillum* for economic and sustainable production of cassava under both rainfed and irrigated conditions of the state. Maximum benefit : cost ratio was also recorded for the application of ½ dose of recommended inorganics in conjunction with green manure and *Azospirillum* (T13) under both rainfed and irrigated conditions during both the years of investigation indicating potential of the treatment for enhanced returns to cassava farmers.

The correlation studies showed a significant positive correlation of yield with all the growth and yield attributes and N, P and K nutrient uptake indicating the dependence of tuber yield of cassava on these parameters.

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) popularly known as tapioca is a native of tropical America (Olsen and Schaal, 2001) and was introduced into India by the Portuguese in the 17th Century. The starchy root is its best known and used product world wide; however the fresh foliage is also used in several regions of the world for animal and /or human consumption. Cassava has high biological efficiency and can substitute cereals with higher carbohydrate and calorific content. Further, the crop plays a significant role in food and nutritional security of rural areas and serves as staple or subsidiary food for about one fifth of the world's population (Edison, 2000). It is also a raw material for starch-based industries in many parts of the world.

Cassava can be grown on a wide range of soils and environments and has the capacity to withstand adverse biotic and abiotic stresses. Globally it is grown in an area of 16.37 million hectares with an annual production of 164.75 million tonnes of tubers. Nigeria occupies first position in both area and production accounting for 16.5 per cent and producing 18.5 per cent respectively. Congo, Brazil, Thailand and Indonesia are the other major cassava growing countries constituting 50 per cent of the area and 64 per cent of the world's production. In India, cassava is grown in an area of 2.7 lakh hectares with an annual production of 7.1 million tonnes (FAO, 2004) and a productivity of 25.93 tonnes per hectare is the highest in the world (Srinivas, 2004). In India, Kerala is the largest cassava cultivating state with 45 per cent of area followed by Tamilnadu with 43 per cent area. The Andhra Pradesh state accounts for 8.4 per cent area (21,500 ha) (CMIE, 2002) and produces 0.17

million tonnes of tubers annually, which is utilized exclusively for industrial purposes (Srinivas and Anantharaman, 2000). Further, cassava in the state is predominantly grown as a rainfed crop. However, in low rainfall areas and certain non-traditional areas, it is cultivated as an irrigated crop. Nutrient requirement of the crop under these two situations varies widely.

Organic manures have been reported to play a vital role in the nutrient management of crops through amelioration of physical and biological conditions of soil and supply of macro and micronutrients to the crops. In India, farm yard manure (FYM) remains the most popular organic manure applied to fields and it can potentially supply about 6.8 million tonnes of N, P and K per year (Sarkar and Rattan, 1995). The response of cassava to organic manures has been studied by several workers and a significant increase in the tuber yield has been reported upon application of FYM in combination with nitrogen, phosphorus and potassium fertilizers (Mandal *et al.*, 1973; Saraswat and Chettiar, 1976; Mohankumar *et al.*, 1976). Among the individual nutrients, maximum response was obtained for the application of FYM with nitrogen. However, Prabhakar and Nair (1987) suggested that green manuring *in-situ* can substitute the practice of using FYM in the cultivation of cassava and can bring down the cost of inputs substantially. Incorporation of green manure crops, particularly cowpea was reported to improve nitrogen content of the soil (Mohankumar and Nair, 1990). However, a decline in the availability of FYM necessitates a search for alternate manures. Vermicompost has been advocated as a good source of nutrients in integrated nutrient management (INM) of field crops (Shraff and Devasthali, 1992). It plays a significant role in improving fertility of the topsoil and boosting crop productivity. But, no studies

have been made on its effect either individually (or) in combination with inorganic fertilizers in cassava.

Biofertilizers, which are formulated cultures of microorganisms, play an important role in sustaining productivity of soils through biological N₂ fixation and enhancing native P availability to crops. Biofertilizers and organic manures together can make significant contribution in maintaining soil health and balancing soil fertility through supply of plant nutrients at an optimum level (Swaminathan, 1992). Among the various bio-fertilizers available, *Azospirillum*, an associative symbiotic nitrogen fixing bacterium known to occur in the rhizosphere of many monocots and dicots has been reported to be important in integrated nutrient management of field crops (Venkateswarlu and Rao, 1983). The beneficial effects of *Azospirillum* in fixing nitrogen and improving the growth and yield of cassava have also been demonstrated by Suchetha *et al.*, (1991).

However, application of organic manures alone to soils is not adequate to meet the nutrient demand of the recent high yielding varieties of crops because of their low nutrient content and slow nutrient releasing nature. Likewise, the use of N, P and K fertilizers under modern intensive farming also will not be sufficient to sustain the food requirement of increasing population. The recent hikes in prices of fertilizers have been compelling the Indian farmers to resort to imbalanced nutrition of crops and thus, leading to reduction in crop yields and also causing negative nutrient balance of 8 to 10 MT of N+P₂O₅+K₂O annually (Tiwari, 2002). The situation with regard to secondary and micronutrients is more alarming. The problem of nutrient depletion is being further aggravated with the decreasing availability and consequent low rates of application of organic manures. It has also

been observed that no single nutrient source, be it inorganic fertilizer, organic manure or biofertilizer, is not in a position to meet the entire nutrient requirement of crops grown in the country. Therefore, combined use of chemical, organic manures and biofertilizers seems to be the only way out to replenish the soil nutrient reserve. In this context, Integrated Nutrient Management (INM) holds great promise in meeting the growing nutrient demands of intensive agriculture and maintaining crop productivity at fairly high level. The conjunctive use of organic and inorganic sources will improve soil health and help in maximizing production as it involves utilization of local resources and, hence turned out to be rational, realistic, eco-friendly and economically viable way of supply of nutrients to crops.

Considerable work has been done on the use of chemical fertilizers along with farm yard manure, but information on the application of vermicompost and green manure as organic sources along with biofertilizers (*Azospirillum*) is rather meager in cassava, particularly under rainfed and irrigated conditions of Andhra Pradesh. Hence, the present investigation was initiated with the following objectives.

1. To study the effect of integrated nutrient management on growth, development and yield of cassava under both rainfed and irrigated conditions.
2. To study the influence of integrated nutrient management on quality parameters of cassava under both rainfed and irrigated conditions.
3. To study the effect of influence of integrated nutrient management on nutrient uptake by the crop under rainfed and irrigated condition.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

The use of organic manures like farm yard manure, green manure, vermicompost etc., along with inorganic and bio-fertilizers has been reported to increase yield and quality of crop produce through supplementation of essential nutrients. Further, the supply of nutrients either through inorganic source (or) bulky organic manures alone does not sustain the productivity of exhaustive crops like cassava. Research results have clearly demonstrated the necessity of integrated nutrient supply and management system for sustainable crop production. The available literature on performance of cassava and other related crops with the application of organic manures (FYM, vermicompost and green manuring), inorganic fertilizers (N, P and K) and bio-fertilizer (*Azospirillum*) either alone or in combination, in relation to crop growth, yield, quality and nutrient uptake has been reviewed in this chapter.

2.1 EFFECT OF INORGANIC FERTILIZERS

Cassava requires a fairly good amount of nutrients for high and economic yields. It is generally considered that cassava exhausts the soil and removes large amount of N and K and this removal is more when cassava receives supplementary irrigation.

2.1.1 Nitrogen

Nitrogen plays an important role in plant nutrition, being an essential constituent of many metabolically active compounds like amino acids, proteins,

nucleic acids, chlorophyll, porphyrins, flavins, purines, pyrimidines, nucleotides, enzymes, coenzymes and alkaloids. Fox *et al.* (1975) reported the critical level of N deficiency to be about 5% in the leaf blade of 4 - 5 months old cassava plants. Mitra *et al.* (1990) reported high nitrogen requirement for cassava. Mohankumar *et al.* (2000) also observed that cassava crop depleted relatively large amounts of nitrogen from the soil, especially when the leaves and stems were removed with roots and the crop's response to applied nitrogen was high, particularly in the hot humid conditions of tropics, where the rate of decomposition of organic matter and loss of mineralized nitrogen was high and where the crop was also grown predominantly.

2.1.1.1 Effect on crop growth, yield and yield attributes

A significant increase in plant height, leaf number and leaf retention due to higher rates of N application was reported by Mandal *et al.* (1971). Natarajan (1975) also reported enhanced plant height of cassava with the application of nitrogen up to 150 kg ha⁻¹. An increase in the tuber yields of cassava in response to higher rates of N application has been reported by several researchers. Saraswat and Chettiar (1976) obtained a response up to 150 kg ha⁻¹ and suggested 100 kg N ha⁻¹ as the most economic dose for tuber yields in cassava. Further, Pillai and George (1978) reported an increase in plant height and tuber weight in response to higher levels of nitrogen in cassava. However, Ashokan *et al.* (1988) stated that nitrogen nutrition had no significant effect on yield attributes of cassava.

Studies by Nair (1982) revealed significantly higher tuber yields in the high yielding hybrid cassava "Sree Sahya" with the application of N at 125 kg ha⁻¹ in

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red-loam soils of south Kerala. He further reported highest plant height and node number at 200 kg N ha⁻¹. But, enhancement in leaf area was highest at 125 kg N ha⁻¹. However, Ramanujam (1982) reported significant increase in LAI, CGR and dry matter production up to 150 kg N ha⁻¹ in cassava. Nair (1982) also observed that increase in N dosage resulted in a significant increase in tuber number and weight in cassava. The studies at CTCRI, Thiruvananthapuram on N response by high yielding hybrids of cassava revealed a decrease in the yield of tubers with N application beyond 100 kg N ha⁻¹ (CTCRI, 1985). Further, Ashokan *et al.* (1988) recorded increased tuber yields of 35 to 67 per cent in a local type and the hybrid H-1687, respectively with the application of nitrogen. They also reported an increase in tuber number, tuber length, plant height, number of leaves and harvest index. Vinod and Nair (1992) also found that increasing N rates up to 150 kg ha⁻¹ was beneficial for cassava production. Investigations by other workers also revealed high tuber yields of cassava at nitrogen levels ranging from 100 kg to 150 kg ha⁻¹ (Mohankumar and Nair, 1994). Further, Geetha and Madhavan Nair (1993) reported a significant positive influence on morphological characters like plant height, number of branches, number of leaves and leaf area index of *Coleus parviflorus* upon 'N' application @ 60 kg ha⁻¹. Similarly, Taleb and Hussain (1997) obtained highest number of branches per plant, greatest leaf area and highest chlorophyll content upon the application of N @ 0.8 g pot⁻¹ along with P and K @ 0.3 and 0.5 g pot⁻¹, respectively in *Coleus blumeli*.

2.1.1.2 *Effect on quality*

Quality of cassava is determined in terms of starch and HCN contents. Black (1973) reported a reduction in starch content of cassava tubers with increased levels of N due to a decrease in the availability of carbohydrates, probably due to the increased rate of protein synthesis and consequent increase in vegetative growth. Similar reduction in the starch content as well as dry matter production with an increase in the N content was reported by Ashokan *et al.* (1988). Tan and Mark (1995) also reported a negative correlation of starch content with higher dose of 'N'. However, improvement in starch content of cassava tuber as a result of higher rates of N application has been reported by Mandal *et al.* (1971); Natarajan (1975); and Pillai and George (1978). Vijayan and Aiyer (1969) reported an increase in starch content of cassava due to N nutrition up to 75 kg ha⁻¹. In contrast, Muthuswamy and Chiranjivi Rao (1979) found that starch content of cassava tubers was not affected by N levels.

The HCN content of cassava tuber was reported to increase with N application (Howeler, 1978; Gomes and Howeler, 1980). An increase in HCN content of the cassava tubers and their consequent poor quality, with N application due to the formation of cyanogenic glucosides was also reported by Nair (1982). Similarly, Mohankumar and Nair (1985) attributed the increase of HCN in N applied treatments to the accumulation of cyanoglucocides as a result of large non protein nitrogen resulting from a deficiency of micronutrients. Ashokan *et al.* (1988) also reported an increase in the HCN content with an increase in the N content.

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Jayakrishnakumar *et al.* (1991) reported a general improvement in tuber quality of cassava with the application of $\frac{3}{4}$ th recommended dose of N.

2.1.1.3 *Effect on nutrient uptake*

Several workers have determined the nutrient uptake pattern with increasing doses of N in cassava (Kanapathy, 1974; Howeler, 1978). Asher *et al.* (1980) reported a removal of 3.5 to 6.0 kg N per tonne of tuber yield produced in cassava. The soil organic carbon and available N were reported to be high under cv. Sree Visakhm fertilized with 100 kg N ha⁻¹ and sown after a green manure cowpea crop of cv. 152 (Nair and Sadanandan, 1985). Further, the favourable influence of N application on N concentration in cassava was reported to be more under moisture stress as compared to the no stress condition (Nayar *et al.*, 1986). Varietal differences in the N content under differing rates of N application was reported by Muthuswamy and Rao (1988). They also observed a positive correlation of N rate with N content of leaf blade at the 5th month.

Kabeerathumma and Mohankumar (1990) reported that continuous application of N fertilizers increased N availability in soil. Badanur *et al.* (1990) also recorded increased soil N levels with fertilizer application over and above crop residue incorporation. Further, Kabeerathumma *et al.* (1999) reported a significant increase in the available N content in a cultivated soil applied with organic N from their five year study on the available NPK content of soils.

2.1.2 **Phosphorous**

Phosphorus plays an important role as a structural component of the cell. It is a constituent of sugar phosphates – ADP/ATP etc. It also has an important role in

energy transformation and metabolic processes of plants. The P requirement of cassava is less as compared to that of nitrogen and potassium. Howler (1978) reported normal Phosphorous concentration of upper fully expanded leaves of cassava to range from 0.3 to 0.5% and the critical concentration has been found to be 0.44%.

2.1.2.1 Effect on growth, yield and yield attributes

Mandal *et al.* (1971) reported that in soils with high P content, skipping of P for the first four years had no significant influence on the tuber yield of cassava, but in acid laterite soils with low P content, yield response was noticed for P application up to 100 kg P₂O₅ ha⁻¹, beyond which the response was non-significant. Further, the optimum economic dose of P in laterite soils was reported to be 45 kg P₂O₅ ha⁻¹. However, Nair and Rajendran (1973) and Pillai and George (1978) reported response of cassava for P doses ranging from 50 to 75 kg P₂O₅ ha⁻¹ in cv. Malayan-4. The results of permanent experiments conducted at CTCRI, however, indicated that exclusion of P from the mineral schedule of cassava had no significant adverse effect on the growth and yield parameters of cassava (CTCRI, 1981). In contrast, Nair *et al.* (1988) reported the response of cassava to graded levels of P in acid laterite soils. They further inferred 50 kg P₂O₅ ha⁻¹ as the optimum P level and 45 kg P₂O₅ ha⁻¹ as the economic dose for cassava production in acid laterite soils.

2.1.2.2 Effect on quality

Prema *et al.* (1975) reported an increase in dry matter, starch and crude protein content of cassava at higher levels of P application. Further, Thomaskurien

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et al. (1976) observed a significant reduction in HCN content of cassava tubers due to P fertilization. In contrast, Susan John *et al.* (1997) reported that neither different levels nor sources of P had any significant influence on the starch content of cassava tubers.

2.1.2.3 *Effect on nutrient uptake*

Okeke *et al.* (1979) reported that application of N and P was most effective in increasing dry matter production and nutrient uptake. Studies by Mello *et al.* (1980) on P saturation of latosol revealed that P availability increased by 0.252 ppm per kg of applied P. Haque and Walker (1980) also reported an increase in the P availability by 0.23 ppm per kg of applied P in acid Sierra Leone soil. Howeler (1981) reported that cassava being a tuber crop; its P requirement and consequently the P uptake are relatively low, compared to those of N and K.

Availability of P in soil was reported to increase markedly with the application of both super phosphate and rock phosphate and inclusion of FYM further accentuated the availability (Pillai *et al.*, 1987). They also reported that continuous application of P_2O_5 @ 100 kg ha⁻¹ for five years resulted in a build up of P up to 399 kg ha⁻¹. Further, Nair *et al.* (1988) reported 25 kg P_2O_5 ha⁻¹ as the optimum dose for high yield and increased P uptake in cassava. However, increased dry matter accumulation due to higher doses of P fertilization and a consequent increase in P uptake has been reported by Mohankumar and Sadanandan (1990). Optimum P dose was reported to vary depending on several factors. According to Kabeerathumma and Mohankumar (1990) uptake of P was high when Mussoorie Rock Phosphate was applied with FYM. They also confirmed that in acid soils

Mussoorie rock phosphate was as good as or even superior to single super phosphate. Kabeerathumma *et al.* (1999) further attributed the increased availability of P noticed on application of inorganic P sources with FYM to the formation of sesquioxide cover and the consequent reduction in phosphate fixing capacity of the soil.

2.1.3 Potassium

Potassium is essential for carbohydrate translocation from the tops to the roots. Normal cassava plants have a 'K' concentration of 1.2 to 3% in the petioles and 0.5 to 1% in the roots. Further, potassium content of petiole varies over a wider range than that of leaf blade and thus appears to be a better indicator of 'K' status of the plant. The critical 'K' content is about 1.2% in the leaf blade and 2.5% in the petiole (Asher *et al.*, 1980). The importance of potassium in cassava production has been reported by several workers (Mandal and Mohankumar, 1969; Samuels, 1970; Kanapathy, 1974; Mohankumar *et al.*, 1976).

2.1.3.1 Effect on growth, yield and yield attributes

Investigations by several workers revealed that cassava responded favourably and yielded highest to the application of 100 kg K₂O ha⁻¹ (Mandal and Mohankumar, 1969). Mohankumar *et al.* (1971) also recorded significantly higher number of tubers per plant at 100 kg K₂O ha⁻¹. Similarly, Rajendran *et al.* (1976) reported that 100 kg K₂O ha⁻¹ was optimum for cassava and further application resulted in luxury consumption. However, Pushpadas and Aiyer (1976) obtained yield responses up to 135 kg K₂O ha⁻¹ for the variety H-165. Similarly, Ashokan and Sreedharan (1977) recorded yield response in cassava up to 135 kg K₂O ha⁻¹ for the variety H-97.

Further, Ashokan and Sreedharan (1980) found an increase in plant height and top yield at higher levels of potassium applied to cassava. Nair *et al.* (1980) compared two indigenous sources of potassium (Schoenite and Syngenite) at different levels with muriate of potash on the yield of cassava in an acid laterite soil. Results revealed the two potassium sources to be on par with muriate of potash in increasing the tuber yield. Among the levels tried, 100 kg K₂O ha⁻¹ was found to be the optimum.

Nair (1982) recorded an enhancement in plant height during the later stages of growth at higher rates of K fertilization. Nair and Aiyer (1985) also observed an improvement in plant height, stem girth and leaf retention at higher rates of K application and recommended 128 kg K₂O ha⁻¹ as the optimum dose for cassava production. However, highest tubers per plant were recorded at 100 kg K₂O ha⁻¹, while greater tuber size was obtained at 150 kg K₂O ha⁻¹. In contrast, Nair and Sadanandan (1987) reported increase in tubers per plant and cassava yields up to 200 kg K₂O ha⁻¹ of potash application. Similarly, Ramanujam and Indira (1987) reported an increase in plant height, accumulation of bio-mass per plant and crop growth rate of cassava with increasing levels of K₂O up to 200 kg ha⁻¹. Jimenez (1990) also reported an increase in plant height, root number and root yield with increasing K rates. The optimum economic and agronomic points were inferred to be 198.6 and 97.3 kg K₂O ha⁻¹, respectively. In contrast, Mohankumar (1999) recorded highest cassava yield at 100 kg K₂O ha⁻¹, which was on a par with the yield obtained at 75 kg K₂O ha⁻¹.

2.1.3.2 *Effect on quality*

The beneficial effect of 'K' nutrition in enhancing the quality of cassava tubers has been widely reported. Fujise and Tsuno (1967) reported that starch content of cassava tubers increased with K application due to an increase in the mass paranchymatous cells, which contained starch granules. The favourable effect of potash nutrition in enhancing starch content of cassava tubers was also observed by Natarajan (1975). High starch yields of cassava tubers with the application of 250 kg $K_2O\ ha^{-1}$ + 600 kg $CaO\ ha^{-1}$ was reported by Pusphadas and Aiyer (1976) in the cassava varieties M-4 and H-165. Mohankumar *et al.* (1976), Ashokan and Sreedharan (1977) and Pillai and George (1978) also reported an increase in the starch content of cassava tubers with increased dose of K application. Further, an increase in the edible portion of cassava tubers with a simultaneous reduction in the crude protein content was reported by Pillai and George (1978).

Ashokan and Sreedharan (1980) reported that application of 'K' alone or in combination with FYM increased the starch content of cassava tubers. Nair *et al.* (1980) also reported maximum starch content of cassava tubers upon application of NPK fertilizers in combination with FYM. They further reported a marked decrease in HCN content of cassava tubers with increasing levels of K application. Improvement in the starch content and quality parameters namely, amylose content, granule size, viscosity and swelling volume with an increase in the rate of K application was reported by Nair and Aiyer (1986).

The effect of higher levels of potassium application in reducing HCN content of cassava tubers was documented by several workers (Nair and Aiyer, 1986; Nair

and Sadanandan, 1987; Ramanujam and Indira, 1987). However, Ashokan *et al.* (1988) reported non-significant influence of K fertilization on the HCN content of cassava tubers.

2.1.3.3 Effect on nutrient uptake

Mohankumar *et al.* (1971) reported that N, P and K application had a significant influence on the K content in petiole of cassava plant. The critical K content was reported to be about 1-2 per cent in the leaf blade, 0.5-1 per cent in roots and 2.5 per cent in the petiole (Kanapathy, 1974). Uptake of K by cassava tubers was reported to increase with increasing N and K application (Rajendran *et al.*, 1976). Nair *et al.* (1980) also observed increased K content in leaf, stem and tubers with increasing K levels. Further, they reported that application of K @ 100 kg K₂O ha⁻¹ maintained a steady level of K in the soil throughout the cropping season, while application above this level resulted in a residual effect.

Thampatti and Padmaja (1987) observed a significant correlation of K uptake with tuber yield and dry matter production of cassava at third month, six month and at harvest stages. Further, Kabeerathumma *et al.* (1999) reported that soil available K was highest when cassava was supplied with 100 kg N + 100 kg K ha⁻¹ followed by a green manure crop of cowpea.

2.2 EFFECT OF ORGANIC MANURES

Traditionally cassava is fertilized with organic manures and response of the crop to organic manures has been studied by several workers (Mandal *et al.*, 1973; Saraswat and Chettiar, 1976; Mohankumar *et al.*, 1976). It has been reported to respond to both bulky and concentrated organic manures (Thampan, 1979).

2.2.1 Farm yard manure

The term “Farm yard manure” refers to the decomposed mixture of dung and urine of farm animals along with the litter (bedding material) and leftover material from roughages or fodder fed to the cattle and occupies an important position among bulky organic manures. FYM can be used for all the horticultural crops as it contains all the major nutrients required for healthy crop growth. On an average, FYM contains 0.5 to 1.0 per cent N, 0.15 to 0.2 per cent P₂O₅ and 0.5 to 0.6 per cent K₂O (Gaur, 1991). A tonne of FYM is estimated to supply 5.0 kg N, 1.9 kg P₂O₅ and 3.0 kg K₂O. Tandon (1992) reported that addition of one tonne of FYM substituted 7.2 kg N, 3.6 kg P and 3.6 kg K. Further, cattle excreta based FYM in India has been estimated to potentially supply 3.3 million tones of N, P and K per year (Gaur *et al.*, 1992).

2.2.1.1 Effect on growth

Tiwari *et al.* (2000) reported that in *Acorus calamus*, application of FYM at the rate of 20 t ha⁻¹ along with basal application of 100 kg N and 100 kg P₂O₅ resulted in a significant increase in all the crop growth parameters. Further, Harinkhede *et al.* (2001) reported that in *Plumbago zeylanica*, growth parameters were highest with the application of FYM @ 10 t ha⁻¹ + NPK at 60:40:30 kg ha⁻¹.

Saharan *et al.* (2001) revealed a significant increase in the growth parameters with the application of FYM @ 20 t ha⁻¹ in Shankpusphi (*Evolvulos alsinoides*). Similarly, Bhaskar *et al.* (2001) reported that application of FYM @ 30 t ha⁻¹ and 180 kg N ha⁻¹ produced significantly higher number of shoots (170.2), and highest leaf stem ratio (2.03) in *Pelargonium graveolens*. Joy *et al.* (2002) also found that

application of FYM @ 20 t ha⁻¹ resulted in increased plant height (90.18 cm), number of leaves per sucker (10.23), number of suckers per clump (57.10) and number of clumps per plant (19.17) compared to control in *Alpinia galanga*.

2.2.1.2 Effect on yield and yield attributes

An increase in the tuber yields of cassava has been reported by several workers with the application of farmyard manure in combination with N, P and K (Mandal *et al.*, 1973). Among the individual nutrients, maximum response was obtained for the application of FYM with nitrogen (Mohankumar *et al.*, 1976). Further, Saraswat and Chettiar (1976) observed that FYM application substantially met the nitrogen requirement of cassava crop. A yield of 32 t ha⁻¹ was recorded for the crop when 66.6 per cent of N was applied as FYM and the rest as calcium ammonium nitrate. Mandal and Mazumdar (1980) reported the highest tuber yield of potato with the application of 90:80:70 kg NPK ha⁻¹ along with FYM @ 15 t ha⁻¹. Studies at CTCRI also revealed that basal application of farm yard manure at 25 t ha⁻¹ was beneficial in enhancing the yield of cassava tubers (Mohankumar *et al.*, 1976 and Pillai *et al.*, 1987).

Minhas *et al.* (1994) observed that application of farm yard manure @ 10 t ha⁻¹ increased potato tuber yield significantly over control (no fertilizer). Similarly, Bohm and Dewes (1997) reported an increase in potato tuber yield with increasing levels of FYM from 0-30 t ha⁻¹.

2.2.1.3 Effect on nutrient uptake

Sabanayagam (1982) observed an increase in the uptake of N and P due to the application of FYM at 25 t ha⁻¹ in cassava. The results of All India Co-ordinated

Research Project on long term fertilizer experiments at CTCRI, Thiruvananthapuram also revealed highest uptake of N in FYM +100 per cent NPK treatment. Similar trend was observed in the uptake of P and K (CTCRI, 1983). Minhas and Amilsood (1993) also reported that application of FYM significantly increased the NPK uptake by potato crop.

2.2.2 Vermicompost

Organic manure produced due to the activity of earthworms is commonly referred as vermicompost. It is a mixture of worm casts, which is a rich source of macro and micro nutrients, vitamins, growth hormones and microflora. The most important effect of earthworms was reported to be the stimulation of microbial activity that occurs in casts which enhances the transformation of soluble nitrogen into protein, preventing their loss by leaching to the lower horizons of the soil (Nowak, 1970). The material ingested by earthworms undergoes biochemical changes and in the ejected casts, the plant nutrients and growth substances are rendered in plant assimilable forms. Thus, fertility of vermicompost is due to the enzymatic activity and microbial activity associated with the earthworms (Kale *et al.*, 1987).

Curry and Byrne (1992) found that earthworms derived nitrogen could supply 30 percent of total crop requirement as it is a potential source of readily available nutrients for plant growth. Shinde *et al.* (1992) reported that the phosphorus content of vermicompost was more than that of FYM. They also reported that vermicompost contains Fe, Mn, Zn and Cu at 17.8, 24.6, 19.2 and 7.6 ppm, respectively.

Jambhelkar (1994) reported that vermicompost contains 2.0 to 2.5 per cent available nitrogen, 1.0 to 1.5 per cent available phosphorus, 1.0 to 1.5 per cent available potassium and also secondary nutrients like Ca, Mg and micronutrients like Fe, Zn, Mn, Cu and Mo in ample quantities. Further, it was also reported to contain enzymes like phosphatase, invertase, chitinase etc., and also growth hormones like indole acetic acid and gibberellic acid. Microbial analysis also confirms that vermicompost is rich in microbes, namely, bacteria like *Azetobacter* and *Azospirillum*, besides number of actinomycetes which help in plant growth.

2.2.2.1 Effect on growth

Nielson (1965) observed improved growth in pastures and other crops which was contributed to the richness of the earthworm fauna and linked to the chemical exudates of earthworms and microbes in association with them. The lush growth of plants obtained by the application of vermicompost was reported to be due to the presence of plant growth promoters like cytokinins and auxins in the worm casts (Krishnamoorthy and Vajranbaiah, 1986).

An extensive study on the effect of vermicompost in balsam, zinnia, coleus, marigold and lady's lace with regards to crop growth revealed on par effect with farm yard manure and inorganic chemical fertilizers (Kale *et al.*, 1991). They also reported that quantity of inorganic fertilizers could be reduced by 25 to 30 per cent in radish, tomato, carrot and brinjal with the application of vermicompost.

2.2.2.2 Effect on yield, yield attributes and quality

In an experiment with potato cv. Kufri Chandramukhi, Patil *et al.* (1997) reported that application of vermicompost @ 4 t ha⁻¹ could substitute 50 per cent of

recommended dose of fertilizer and produced 53.46 per cent more yield over recommended dose of fertilizer. Saikia and Rajkhowa (1998) obtained highest marketable tuber yields in potato with the application of 2.5 t ha⁻¹ vermicompost along with 75 percent recommended NPK at 120:100:100 kg ha⁻¹, respectively. Similarly, Patil *et al.* (1998) reported highest yield and net income in carrot with the application of vermicompost @ 2 t ha⁻¹ + recommended rate of inorganic fertilizers (NPK at 100:75:75 kg ha⁻¹). Ravindrababu (1999) also reported that application of vermicompost @ 15 t ha⁻¹ along with 100 per cent recommended dose of NPK gave highest yield in carrot.

Ghosh and Sarkarsumana (2000) reported that vermicompost developed from animal and agricultural waste had higher nutrient and microbial population and one tonne of compost material could supply adequate nutrients (15 kg nitrogen, 8 kg phosphorus, 10 kg potash) to substitute partly for chemical fertilizers. An increase in the number of tubers, fresh and dry tuber yield and steroid content of *Chlorophytum borivillianum* was also reported by Paturde *et al.* (2002) with the application of vermicompost of 5 t ha⁻¹.

2.2.3 Green Manuring

Vigna (Cowpea) was reported to be a superior green manure crop for cassava cultivated on acid infertile soils of Colombia (CIAT, 1975). Sasidhar and Sadanandan (1976) and Mattos *et al.* (1980) reported that cassava was benefited by the rotation and association of cowpea. Green manuring *in situ* or incorporation of green matter was reported to supplement nitrogen equivalent to 50 kg N ha⁻¹ in rice and other dry land crops besides recycling P and K and improving soil organic

carbon. Leguminous crops like cowpea, green gram and black gram were reported to be useful as green manure for incorporation of the stalks after harvest of seeds or pods. These leguminous crops were able to fix varying amounts of N from 85 to 500 kg N ha⁻¹ and after considering various losses (leaching, denitrification, etc.), a modest average estimate of 50 kg N ha⁻¹ was believed to be available to the crop (Gaur and Singh, 1982). Green manuring was also suggested by Gaur *et al.* (1984) for enrichment of soil fertility and sustainability in the long run. Similarly, Joseph (1986) advocated *in situ* sowing and incorporation of short duration green manures to increase the soil fertility and productivity. Prabhakar and Nair (1987) also suggested that green manuring *in situ* can eliminate the practice of using FYM in the cultivation of cassava and can bring down the cost of inputs substantially, especially on Nitrogen. The benefits credited to leguminous green manure crops include increase in organic matter content and available plant nutrients and improvement in the microbiological and physical properties of the soil, besides enhancing the fertility status. Of these, the role of green manures in supplying plant nutrients particularly N, is most prominent. It has been estimated that global N flux from symbiotic fixation is about twice the input from fertilizers (Paul, 1988).

The beneficial effects of raising cowpea and incorporation to cassava in field were reported by Mohankumar and Nair (1990). Howeler (1993) advocated interplanting of the green manure crops in between cassava rows at the time of planting cassava and uprooting and mulching of the green manures after 1½ to 2 months or alternatively, to seed the green manures about 1-2 months before the cassava harvest and plant the next cassava crop after incorporation of the green

manures in drier areas. He also suggested growing and mulching of green manures for increased cassava yields and control of weeds and soil erosion. The important role of green manuring in supplying major and minor nutrients in addition to increasing the nutrient availability and moisture holding capacity was reported by Krishnamoorthy and Mathan (1995).

2.2.3.1 *Effect on growth*

Anilkumar and Sasidhar (1987) observed lower values of LAI in cassava when intercropped with cowpea. According to them, the smothering effect of cowpea, raised as a green manure intercrop was evident in the form of yellowing of the older leaves of cassava resulting in reduced leaf area duration and number of functional leaves, thereby causing a reduction in leaf area index. However, such significant differences in LAI were not observed after fifth month of cassava planting, due to the absence of competition. Similarly, Balakrishnan and Thamburaj (1993) reported a severe reduction in plant height of cassava, before the fifth month, in cassava intercropped with cowpea raised for green manure. However, they recorded highest plant height of cassava when intercropped with blackgram and also raised for green manure.

2.2.3.2 *Effect on yield, yield attributes and quality*

Chatterjee *et al.* (1979) reported higher tuber yield from cassava intercropped with leguminous green manure crop due to the supplementary relationship that existed between the main crop and the leguminous intercrop. Similarly, Meerabai *et al.* (1992) reported that cassava performed better under the intercropping system with leguminous green manure crop than under monoculture. Kabeerthumma *et al.*

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(1999) also observed that incorporation of cowpea *in situ* with P as super phosphate produced tuber yields, on par with half dose of FYM in cassava.

2.3 BIOFERTILIZERS

The increasing demand for nitrogen in cassava production could be solved by the enhancement and exploitation of biological nitrogen fixation. A shortage of chemical nitrogen fertilizers and their rising costs have necessitated a deeper understanding and application of using the natural and renewable biological resources to meet at least a part of the nitrogen requirement of the crops (Webber *et al.*, 1980). In the wake of high requirement of nitrogen for higher yields, the process of biological nitrogen fixation has come to the forefront. The nitrogen fixing bacteria belonging to the genus, *Azospirillum* which grow in association with roots of crop plants (Anonymous, 1981) have the potential to add nitrogen to the soil and thus reducing the nitrogenous fertilizer requirement of crop plants. Howeler (1980) reported that even a small fraction counted in a marginal crop like cassava where application of inorganic commercial fertilizers was considered a luxury. Tilak (1991) also opined that biofertilizers like *Azospirillum* can provide an economically viable lever for realizing the ultimate goal of increasing productivity. However, Motsara and Mann (1992) reported that biofertilizers would never be able to substitute the requirement of chemical fertilizers and can only be considered as complimentary and supplementary sources of plant nutrients.

2.3.1 Effect on growth

Bioinoculants like *Azospirillum* act as a supplement for N fertilizers and are employed to enhance the growth of crops and reduce their mineral fertilizer

requirement. An increase in the growth parameters due to *Azospirillum* inoculation have been reported in wheat, sorghum and Pearl millet (Kapulnik *et al.*, 1981), cotton (Purushothaman and Gunasekaran, 1981) and sweet potato (Palanisamy, 1985). The promotive effect of *Azospirillum* on plant height, stem girth, number of leaves, leaf area index and dry matter production of cassava has also been reported by Suchetha (1989). Further, Jadhav *et al.* (1998) also reported highest dry weight of vines of sweet potato cv. Narayangaon Local No. 1 on application of *Azetobacter* and *Azospirillum* biofertilizers.

The reported increase in growth rate due to *Azospirillum* was ascribed to its direct role in N fixation and also the production of phytohormones like indole acetic acid, gibberellins and cytokinin like substances (Reynders and Viassak, 1979; Tien *et al.*, 1979; Govindan and Purushothaman, 1984). This increase in growth parameters was also attributed to the increased uptake of nutrients such as N, which was made available by the activity of inoculated bacteria (Okon and Kapulnik, 1986; Lin *et al.*, 1983; Okon, 1982). According to Claypool (1936) and Childers (1966) the absorbed nitrogen combining with carbohydrates synthesized by leaves through increased photosynthetic activity might have led to the formation of amino acids, proteins to build up of new tissues.

2.3.2 Effect on yield, yield attributes, quality and nutrient availability

Kandaswamy *et al.* (1988) reported that joint inoculation of VAM and *Azospirillum* significantly enhanced the shoot length and its dry weight and tuber weight and starch content of cassava. Similarly, considerable increase in tuber yield, dry matter and starch content of cassava was also reported by Suchetha (1989) with

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Azospirillum inoculation and application of nitrogen and micronutrients. Yassin *et al.* (1994) also reported highest yields in sweet potato with root and soil inoculation of *Azospirillum* supplemented with 26 kg N ha⁻¹. Further, combined application of *Azospirillum* and phosphobacterium along with 100 per cent recommended NPK was reported to result in increased starch content of potato tubers (Mahendran and Chandramani, 1998). An increase in potato tuber yields was also reported by Mahendran and Kumar (1998) with *Azospirillum* soil inoculation and application of recommended NPK fertilizers. Similarly, Jha and Mishra (1999) reported highest tuber yield in sweet potato, fertilized with 40 kg N ha⁻¹ supplemented with 10 kg *Azospirillum* ha⁻¹ as soil application, followed by 40 kg N ha⁻¹ supplemented with 2 kg *Azospirillum* ha⁻¹ as vine dipping. The highest net income and benefit : cost ratio were obtained with the treatment, 40 kg N ha⁻¹ supplemented with 10 kg ha⁻¹ *Azospirillum* as soil application.

Karthikeyan (1981) reported higher post harvest available N status in the soil due to *Azospirillum* inoculation in sorghum crop. Venkatachalam (1983) also reported similar high nitrogen availability in soil at harvest owing to inoculation of *Azospirillum* and application of N.

2.4 INTEGRATED NUTRIENT MANAGEMENT (INM)

The results of a large number of experiments on manures and fertilizers conducted in the country revealed that neither the inorganic chemical fertilizers, nor organic sources can alone achieve the production sustainability of soil as well as crops under high intensive cropping systems. An integrated approach involving organic manures, inorganic fertilizers and biological sources will therefore enhance

the building of soil fertility on a sustainable basis, since the system would supply almost all the nutrients in a judicious way, besides increasing the nutrient use efficiency and improving the soil physico-chemical properties. The efficacy of combined use of chemical fertilizers and organic manures has also been documented by many workers (Madhumitadas *et al.*, 1991; Mandal *et al.*, 1992; Gupta *et al.*, 1992). The concept of integrated nutrient management was developed in this context and is defined as the continuous improvement of soil productivity on long term basis through appropriate use of inorganic fertilizers and organic manures, including green manures and their scientific management for optimum growth, yield and quality of different crops and cropping systems in specific agro-ecological situations (Palaniappan and Annadurai, 1999).

2.4.1 Effect on growth, yield, yield attributes, quality and nutrient uptake

Complimentary effect of FYM along with inorganic fertilizer was reported by Mandal *et al.* (1973) who reported highest tuber yield in tapioca with 100 kg each of N, P and K along with 12.5 t ha⁻¹ of FYM. Badrova and Gavrilova (1973) found that application of FYM at 40 t ha⁻¹ along with 60 kg ha⁻¹ each of N, P and K gave highest tuber yield in potato compared with single application of NPK. Further, Saraswat and Chettiar (1976) observed that FYM application substantially met the nitrogen requirement in cassava crop. An yield of 32 t ha⁻¹ was recorded when 66.6 per cent of N was applied as FYM and the rest as calcium ammonium nitrate. Mohankumar *et al.* (1976) also reported highest tuber yield of 27.1 tonnes/ha with 100 kg each of N, P and K along with 12.5 tonnes/ha of FYM. They further observed that the effect of inorganic fertilizers and FYM on cassava tuber

production was additive. Mandal and Mazumdar (1980) also obtained the highest potato tuber yield with the application of 90:80:70 kg NPK ha⁻¹ along with FYM @ 15 t ha⁻¹.

Guptha and Saxena (1981) reported that the nitrogen and phosphorus application to potato increased the phosphorus accumulation in all parts at almost all growth stages. Prasad *et al.* (1982) reported that the highest potassium content was found in NPK + FYM treatment. The mean removal of potassium by six crops of potato was ranged from 16.4 to 225 kg ha⁻¹.

CTCRI (1983) reported that most of the cassava varieties were capable of producing 30 tonnes fresh tubers per hectare under favourable conditions, removed about 180-200 Kg N, 15-22 Kg P and 140- 160 Kg K per hectare. Factors like varieties variation, fertilizer application, water management and the cropping system were reported to influence the nutrient uptake/ removal in cassava. Further, Grewal and Treham (1984) reported a significant increase in the production of large tubers with 80 kg P or 30 tonnes of FYM ha⁻¹. The higher yield was mainly due to improvement in tuber size. Sahota and Govindakrishnan (1984) reported that economic optimum aggregate and medium sized tuber yield in potato could be obtained with 20 t FYM ha⁻¹ supplemented with 120 kg N + 22.5 kg P ha⁻¹ (or) 60 kg N + 17.2 kg P ha⁻¹.

Nayar *et al.* (1986) reported 142 N - 23 P - 91 K nutrient removal (Kgs/ha) by M - 4 cassava variety under rainfed conditions compared to 188 N - 24 P - 109 K nutrient removal (Kgs/ha) under irrigated conditions. Further, 173 N - 25 P - 108 K and 213 N - 29 P - 148 K nutrient removal (Kgs/ha) was reported for Sree Sahaya

variety, while Sree Visakhm variety recorded 156 N - 22 P - 111 K and 225 N - 30 P - 147 K nutrient removal (Kgs/ha) under rainfed and irrigated conditions, respectively indicating the influence of cassava varieties and water management on N, P and K nutrient removal/ uptake by cassava. The level of fertilizer application was also reported to influence N, P and K uptake by cassava. Application of 50 N - 100 P - 50 K (kg/ ha) resulted in 117 N - 16 P - 71 K and 167 N - 23 P - 92 K (kg/ha) nutrient removal under rainfed and irrigated conditions, respectively. Further, the application of 150 N - 100 P - 150 K (Kg/ha) had resulted 170 N - 26 P - 117 K and 224 N - 34 P - 149 K (kg/ha) nutrient removal, while application of 200 N - 100 P - 200 K (kg/ha) had resulted in 192 N - 25 P - 129 K and 242 N - 36 P - 166 K (kg/ha) nutrient removal under rainfed and irrigated conditions, respectively.

Ravindran and Balanambisan (1987) observed that under low land situation the combination of FYM 10 t ha⁻¹ and N, P and K @ 75, 50 and 75 kg ha⁻¹ respectively recorded a highest yield of 19.6 t ha⁻¹ in sweet potato. The studies of Kabeerathumma *et al.* (1988) in a ten year trial on the effect of manures and fertilizers on cassava tuber production also revealed highest tuber yield from continuous application of FYM + NPK.

Nayar and Mohankumar (1989) reported that incorporation of haulms of cowpea eliminated the need for application of farm yard manure to cassava and also reduced the requirement of inorganic nitrogen by 50 per cent. Minhas (1994) found that NPK uptake by all three crops in a sequence (potato, maize, potato) increased with increase in NPK doses and FYM. Uptake of different nutrients was also

reported to be significantly higher with vermicompost than FYM (Srinivasareddy and Umamahesh 1995).

Amanullahkhan (1997) investigated the influence of fertilizer levels, intercropping and organic manures on the growth and yield of cassava and reported an increase in plant height, leaf area index, dry matter production, crop growth rate, relative growth rate and net assimilation rate with the application of farm yard manure @ 25 tons/ha, compared to control (no manure).

Cadavid *et al.* (1998) envisaged that application of NPK fertilizer significantly increased root and top bio-mass and reduced HCN content. Ravindrababu (1999) observed that the uptake of N, P and K significantly increased with increased vermicompost level in carrot and highest uptake was recorded in the 15 t ha⁻¹ vermicompost.

Sankar *et al.* (1999) suggested that application of FYM at 12.5 t ha⁻¹ + P at 30 kg ha⁻¹ resulted in increased plant height stem girth, root length, root girth and starch content. Sheu *et al.* (2000) on the effect of organic and inorganic fertilizers on growth and yield of *Dioscorea doryophora* revealed that the growth and yield (23 t ha⁻¹) were similar in both organic (goat manure @ 20 t ha⁻¹) and inorganic sources (NPK 147:144:120 kg ha⁻¹).

The long term fertilizer experiments on cassava revealed that the balanced application of NPK alone (32.8 and 34.2 per cent) and along with FYM (33.2 and 33.5 per cent) resulted in the highest starch content in the initial and 13th year respectively (Susan John *et al.* 2003).

Nayar *et al.* (2003) studied the response of cassava to *Azospirillum* and *Phosphobacterium* bio-fertilizers in combination with chemical fertilizers and farm yard manure. The results revealed that conjoint use of bio-fertilizers with recommended dose of farm yard manure, K, 50% N and P resulted in cassava tuber yields on par with full recommended dose of farm yard manure and NPK suggesting the possibility of reducing inorganic N and P dosage in cassava production. Vasudevan *et al.* (2003) also reported that bio-fertilizers (*Azospirillum* and *Phosphobacterium*) applied along with NPK fertilizers helped the plants in utilization of the applied inorganic nutrients more effectively, thereby reducing the dose of inorganic N and P fertilizers in cassava production under rainfed conditions of Salem district of Tamilnadu state in India.

Nedunchezhiyan *et al.* (2004) reported that combination of 50 per cent of inorganic N with any organic manure (FYM, poultry manure, pig manure) to supply the remaining 50 per cent of recommended N, resulted in significantly higher vine and tuber yields in rainfed sweet potato. Similarly, Jospesh and Abraham (2004) indicated that application of 50 per cent of recommended NPK + 50 per cent of recommended FYM recorded the maximum number of tubers per plant, tuber length, tuber girth and tuber yield of cassava.

Suja *et al.* (2005) observed that integrated use of biofertilizers (*Azospirillum* and *Phosphobacterium*) with recommended dose of FYM and K and 50 per cent of N and P produced tuber yield of cassava on par to recommended fertilizer dose suggesting a possibility for reducing N and P fertilizer to 50 per cent. Further, they

reported favourable crop growth by enhanced tuber and whole plant biomass as well as N, P and K uptake by the crop.

2.5 CORRELATION STUDIES

Ramanujam and Biradar (1987) reported a significant positive association of various physiological parameters namely petiole length, specific leaf weight, net assimilation rate, crop growth rate, total biomass production with tuber yield of cassava. Similarly, Amanullahkhan (1997) had also reported a significant positive correlation between tuber yield and growth parameters like plant height, LAI and dry matter production and yield attributing characters namely number of tubers per plant, length and girth of cassava tubers.

Amarchandra and Tiwari (1987) noticed that there was a positive correlation between tuber weight per plant, tuber girth and tuber yield. Chowdhury and Ravi (1990) observed that the mean crop growth rate and net assimilation rate during the crop growth period showed positive but non-significant correlation, whereas mean dry matter partitioning ratio revealed a significant positive correlation in sweet potato. Further, Naskar *et al.* (1992) reported that a significant positive correlation existed between the characters such as number tubers per plant, tuber girth, and yield of marketable tubers. Li (1965); Kamalam *et al.* (1977); Amarchandra and Tiwari (1987) also observed high degree of positive association between number of tubers per plant and tuber girth with the tuber yield of sweet potato.

Correlation studies by Jayatilake (2002) in onion revealed that a positive and significant association of yield with plant height, number of leaves per plant, leaf area index, total dry matter production, bulb weight and diameter and N uptake.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present investigation on “Integrated nutrient management for cassava (*Manihot esculenta* Crantz.)” was undertaken at Agricultural Research Station, Peddapuram, East Godavari district of Andhra Pradesh during 2002-2003 and 2003-2004 and the materials and methods employed during the course of investigations are presented briefly in this chapter.

3.1 LOCATION

The experimental site is located in upland areas of East Godavari district at Agricultural Research Station, Peddapuram situated in the North Coastal Zone of Andhra Pradesh at 82°03' East longitude, 17°4' North latitude and 30.48 m above mean sea level.

3.2 WEATHER DURING CROP PERIOD

The weather parameters recorded during the crop growth period from June'2002 to January'2003 and June'2003 to January'2004 are presented in Annexure-I and depicted in Figs. 1 and 2. A total rainfall of 536 mm was received in 35 rainy days during 2002-2003, while a total rainfall of 1024.10 mm was received in 50 rainy days during 2003-04, during the cropping period. The maximum temperatures ranged from 29.6 to 35.6°C during 2002-03 and 29.1 to 38.2°C during 2003-04, while the minimum temperatures varied between 15.3 to 26.7°C during 2002-03 and 16.2 to 26.7°C during 2003-04. Further, the relative humidity fluctuated between 70 to 93 per cent at 7.16 hr and 45 to 74 per cent at 14.00 hr during

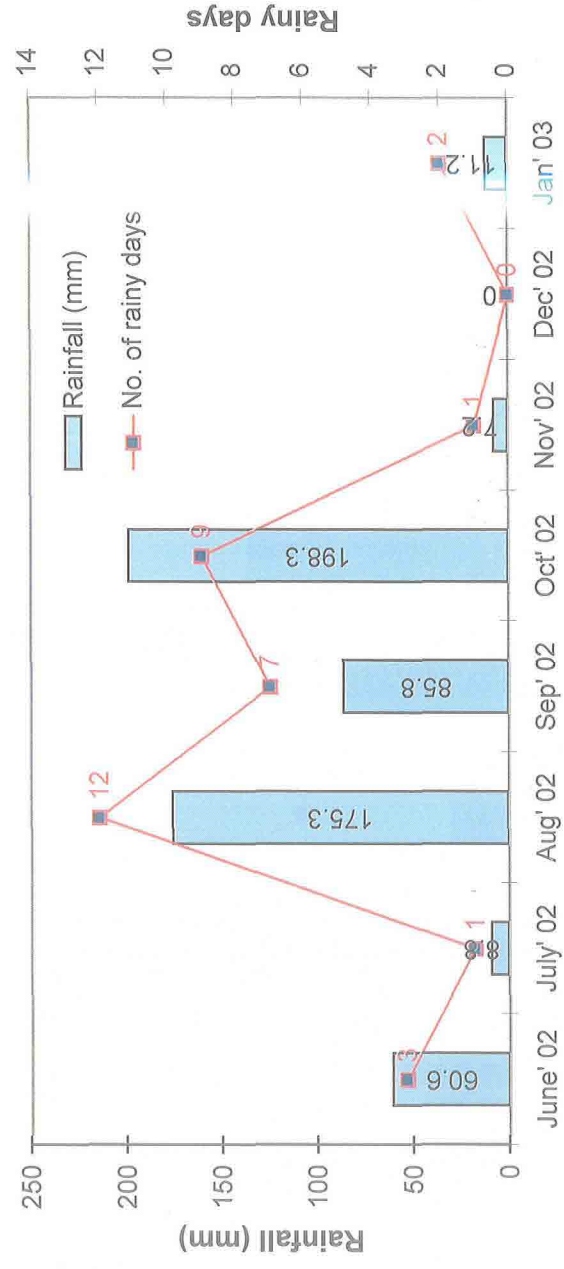
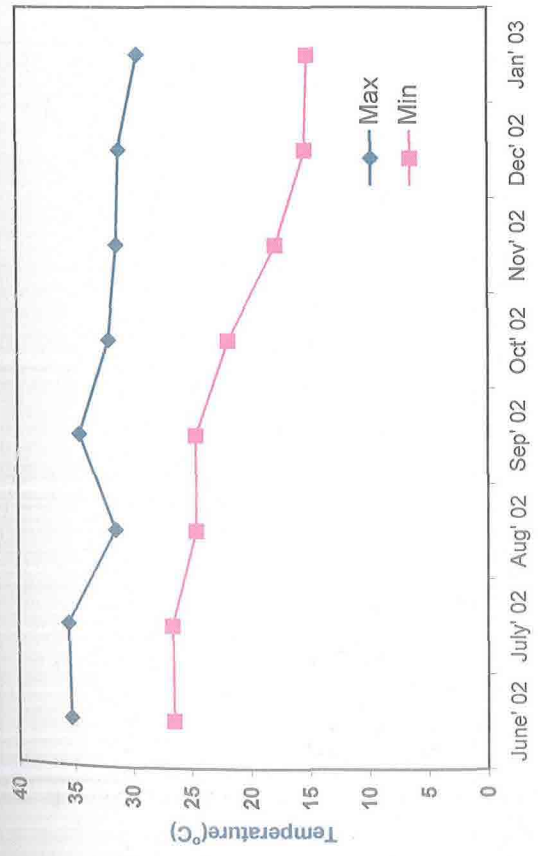
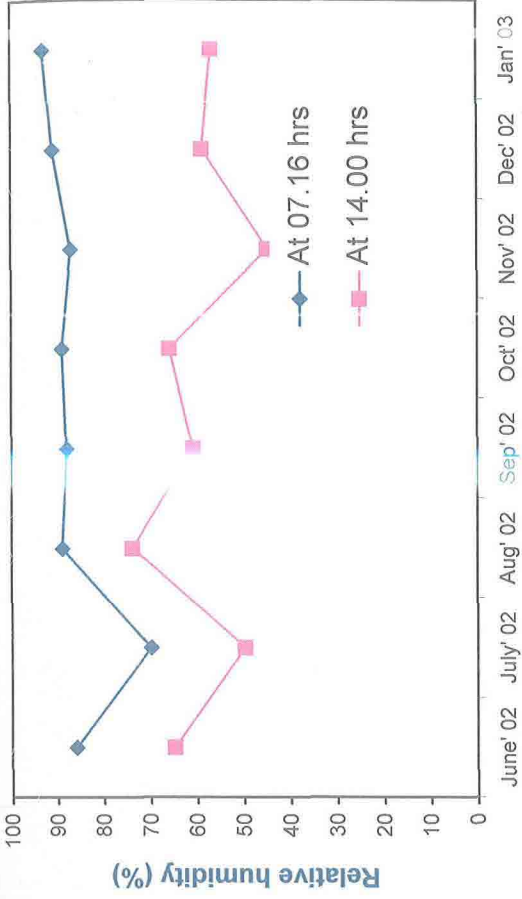


Fig.1. Weather during 2002-03 crop period

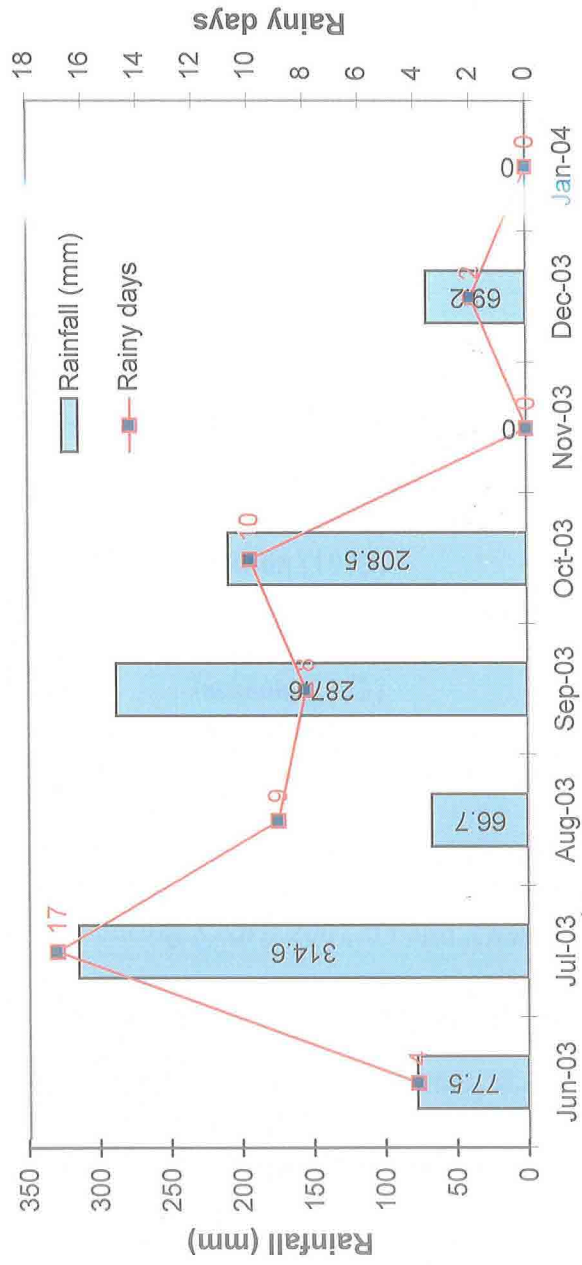
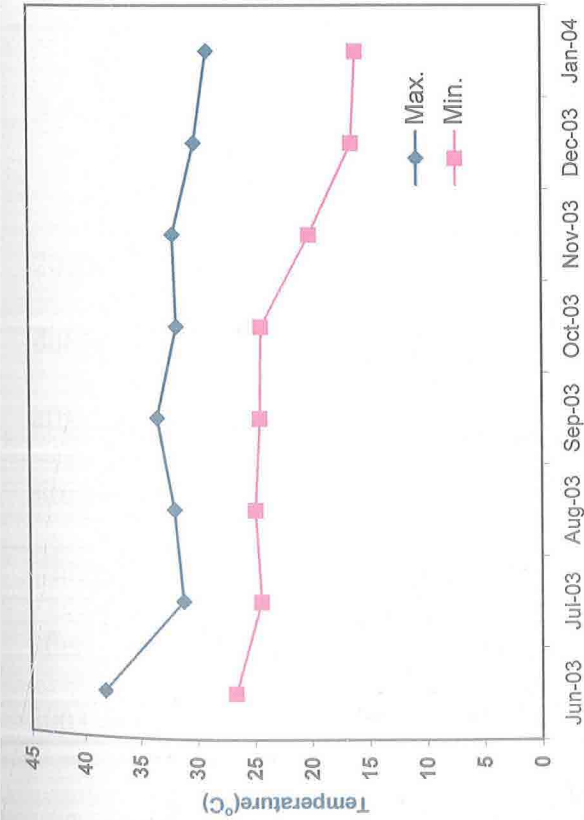
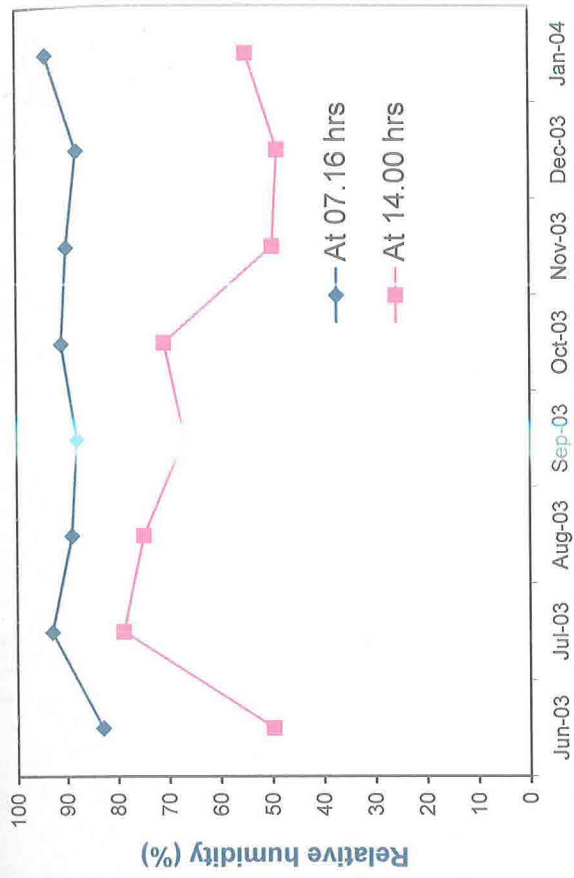


Fig. 2. Weather during 2003-04 crop period

2002-03; and 83 to 94 per cent at 7.16 hr and 49 to 79 per cent at 14.00 hr during 2003-04.

3.3 SOIL

The experimental soils (field number 7 during 2002-03 and field number 8 during 2003-04) were well drained sandy loams, low in organic carbon and available nitrogen; medium in available phosphorus and high in available potassium; and possessing normal pH and electrical conductivity. Physico-chemical characteristics of the experimental soils are presented below:

Physico-chemical characteristic	F.No.7	F.No.8	Method adopted
Organic carbon (%)	0.28	0.34	Walkey and Black (1934)
pH (1:2 solution)	6.4	6.8	Jackson (1973)
EC (m.mhos/cm)	0.24	0.32	Jackson (1973)
Available Nitrogen (kg/ha)	220.5	224.2	Subbaiah and Asija (1956)
Available Phosphorus (kg/ha)	24.52	26.16	Olsen <i>et al.</i> (1954)
Available Potassium (kg/ha)	346.34	350.18	Jackson (1973)
Texture	Sandy loam	Sandy loam	Piper (1960)

3.4 SEASON

The two field experiments were conducted during *Kharif* 2002-03 and *Kharif* 2003-04. Planting of setts in the nursery was taken up during the first week of June during 2002 and 2003. Further, planting of the sprouted setts in main field was affected one week after planting in the nursery for both rainfed and irrigated situations to coincide with normal planting season of cassava under local agro-climatic conditions of Peddapuram. Harvest of the crop was affected seven months after planting in the main field during the second fortnight of January 2002 and 2003, respectively.

3.5 EXPERIMENTAL DETAILS

3.5.1 Variety

Sree Prakash (S-856), a short duration (7 months), dwarf and non-branching variety with good leaf retention and tuber cooking quality, which is very popular among farming community, was selected for the present investigation.

3.5.2 Layout

An exhaust crop (Maize) was raised first in the experimental fields without any fertilizer application before laying out the field experiments during both years of study to obtain correct response of crop to applied nutrient treatments. The experiments consisting of 13 treatments were laid out in randomized block design with three replications under both rainfed and irrigated situations. Details of the treatments are present below:

- T1: Recommended dose of inorganic fertilizers (RDF) (60:60:60 kg NPK/ha for rainfed and 100:100:100 kg NPK/ha for irrigated situation)
- T2: RDF +FYM
- T3: RDF+FYM+*Azospirillum*
- T4: 2/3 RDF+FYM+*Azospirillum*
- T5: 1/2 RDF+FYM+*Azospirillum*
- T6: RDF+Vermicompost
- T7: RDF+Vermicompost+*Azospirillum*
- T8: 2/3 RDF+Vermicompost+*Azospirillum*
- T9: 1/2 RDF+Vermicompost+*Azospirillum*
- T10: RDF+Green manuring with cowpea
- T11: RDF+ Green manuring with cowpea+*Azospirillum*
- T12: 2/3 RDF+ Green manuring with cowpea+*Azospirillum*
- T13: 1/2 RDF+ Green manuring with cowpea+*Azospirillum*



RAINFED EXPERIMENT

R1	T7	T5	T1	T12	T13	T10	T11	T6	T9	T2	T8	T3	T4
R2	T1	T3	T2	T4	T11	T5	T10	T8	T12	T6	T7	T13	T9
R3	T4	T6	T8	T3	T1	T7	T12	T10	T13	T11	T9	T5	T2

IRRIGATED EXPERIMENT

R1	T4	T3	T8	T2	T9	T6	T11	T10	T13	T12	T1	T5	T7
R2	T2	T5	T9	T11	T13	T10	T12	T7	T1	T3	T8	T6	T4
R3	T9	T13	T7	T6	T12	T8	T10	T5	T11	T4	T2	T3	T1

Design : RBD Replications : 3 Gross plot size : 5.4m x 4.5m Net plot size : 4.5m x 3.6m

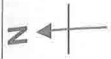
Layout plan of the experimental field during 2002- 03

The above 13 treatments were imposed both under rainfed and irrigated situations during both years of study. Irrigations were not given for the experiment under rainfed situation. However, irrigations were given under irrigated situation as and when 50 per cent moisture depletion was recorded on the basis of gravimetric method.

Moisture in the soil was determined using gypsum blocks and the level was calculated at 15 cm soil depth. Available soil moisture content was obtained from the moisture content at field capacity, determined a day after irrigation, while permanent wilting point was obtained from moisture content studies of the field on withering of the test plant (sunflower). Further, the soil moisture content was measured on alternate days on gravimetric method for determining 50 per cent of available soil moisture content and scheduling the irrigations to the irrigated experiment.

In the present investigation, field capacity of the experimental plot at 15 cm soil depth was 24.57 per cent during 2002-03 and 26.82 per cent during 2003-04, while the moisture content at permanent wilting point was 8.62 per cent during 2002-03 and 7.14 during 2003-04. Therefore, irrigations were given as and when the soil moisture reached 7.98 per cent during 2002-03 and 9.34 per cent during 2003-04 i.e., 50 per cent of available soil moisture (15.95% and 18.68%, respectively).

The manures and fertilizers were applied as per the above treatment combinations. The entire dose of P_2O_5 (60 kg/ha under rainfed and 100 kg/ha under irrigated situation) was applied as basal in the form of single super phosphate @ 375 kg/ha under rainfed and 625 kg/ha under irrigated condition, while nitrogen



RAINFED EXPERIMENT

R1	T5	T13	T9	T12	T6	T8	T1	T11	T3	T7	T10	T4	T2
R2	T11	T3	T10	T8	T2	T4	T6	T13	T9	T5	T12	T7	T1
R3	T1	T4	T13	T7	T5	T12	T8	T10	T2	T9	T11	T3	T6

IRRIGATED EXPERIMENT

R1	T5	T13	T9	T12	T6	T8	T11	T1	T3	T7	T10	T4	T2
R2	T3	T10	T8	T2	T7	T11	T9	T4	T6	T13	T5	T12	T1
R3	T1	T4	T13	T7	T5	T12	T8	T10	T2	T9	T11	T3	T6

Design : RBD Replications : 3 Gross plot size : 5.4m x 4.5m Net plot size : 4.5m x 3.6m

Layout plan of the experimental field during 2003-04

(60 kg/ha under rainfed and 100 kg/ha under irrigated situation) and potassium (60 kg/ha under rainfed and 100 kg/ha for irrigated situation) were applied as Urea @ 130 kg/ha under rainfed and 217 kg/ha for irrigated situation; and muriate of potash @ 100 kg/ha under rainfed and 167 kg/ha under irrigated situation, respectively in three splits as top dressing at 30, 60 and 90 days after planting around the plant at 10 cm distance in a circular ring of 5 cm depth followed by earthing up of the soil.

Farm yard manure and vermicompost were applied @ 12.5 tonnes/ha and 5 tonnes/ha, respectively one week before planting and were thoroughly incorporated into the soil, while cowpea (green manure crop) was sown @ 50 kg/ha at the time of planting of cassava and was incorporated @ 15 tonnes/ha at 50 per cent flowering. Further, *Azospirillum* was applied in the plots as per the treatments and thoroughly incorporated before planting of cassava seedlings. The nutrient contents (dry weight basis) of FYM, Vermicompost and green manure crop (cowpea) used in the present investigation are given below.

Particulars	Nutrient content(%) and quantity added (Kg/ha)					
	N		P		K	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
FYM	0.41	0.46	0.30	0.26	0.40	0.42
Quantity added to soil	51.25	57.50	37.50	32.50	50.00	52.50
Vermicompost	1.47	1.51	1.24	1.21	1.58	1.60
Quantity added to soil	73.50	75.50	62.00	60.50	79.00	80.00
Greenmanure(cowpea)	0.58	0.54	0.18	0.15	0.58	0.60
Quantity added to soil	23.20	21.60	7.20	6.00	23.20	24.00

3.6 CULTIVATION

3.6.1 Nursery

Well matured, healthy and disease free stems of previous season of Sree Prakash (S-856) variety were used as planting material (Plate 1) for the experiments. The bottom (5 to 10 cm) and top 1/3rd portion of the stems was discarded and the remaining part was cut into setts of 20 cm length. These setts were treated in a solution of 3 g Dithane M-45 + 2 ml of Dimethoate per liter of water for five minutes before planting in the nursery at 5 x 5 cm spacing on a raised nursery bed. The nursery beds were watered regularly and one week old uniform healthy sprouted settlings were selected for planting.

3.6.2 Main field preparation

The land was thoroughly ploughed to a depth of 30 cm and brought to good tilth and the plots were laid out as per the layout plan. Plantings were then affected in the plots with the young healthy sprouted settlings obtained from the nursery at a spacing of 90 x 90 cm and 5 cm depth.

3.6.3 After care

Gap filling was taken up one week after planting to ensure optimum plant population in each plot. The removal of excess shoots was done on 15th day after planting and retained two healthy opposite shoots per plant. Further, hand weeding in the experimental plots was taken up on 30, 60 and 90 days after planting and the plots were kept weed free. Prophylactic plant protection measures were adopted in the experimental plots against the important pests like red spider mite and diseases like cassava mosaic virus.

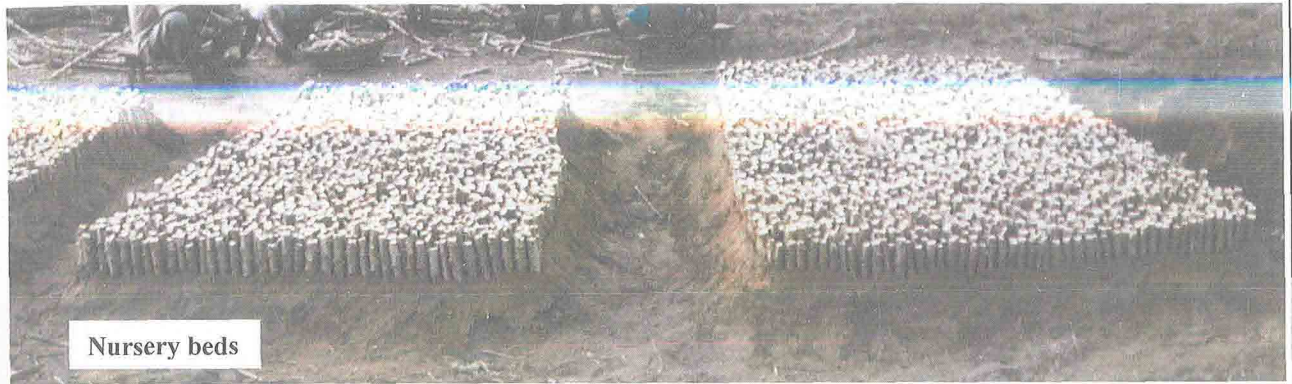
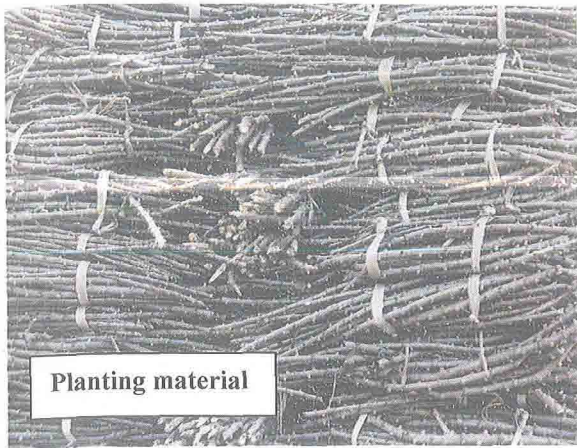


Plate 1. Planting material, nursery and general view of experimental plots

3.6.4 Irrigation

Irrigations were not given for rainfed experiments conducted during *Kharif* 2002-03 and *Kharif* 2003-04. However, based on 50 per cent depletion of available soil moisture, eight irrigations during *Kharif* 2002-03 and four irrigations during *Kharif* 2003-04 were given as detailed below for the irrigated experiments.

Season	Irrigation number	Date of irrigation	Crop stage
<i>Kharif</i>	1	01.07.2002	16 DAT
2002-03	2	15.07.2002	30 DAT
	3	31.07.2002	45 DAT
	4	01.10.2002	106 DAT
	5	01.11.2002	137 DAT
	6	18.11.2002	154 DAT
	7	06.12.2002	172 DAT
	8	22.12.2002	188 DAT
	<i>Kharif</i> 2003-04	1	20.10.2003
2		05.11.2003	152 DAT
3		22.11.2003	169 DAT
4		08.12.2003	185 DAT

3.6.5 Harvest

The plants were harvested from net plot area of each experimental plot in each season by pulling out carefully after seven months from the date of planting in the main field. Further, fresh weights of leaf, stem and tubers were recorded at the time of harvest.

3.7 OBSERVATIONS

The following observations were recorded on five randomly selected labeled plants from the net plot in each treatment in each replication.

3.7.1 Morphological parameters

3.7.1.1 *Plant height*

Height of the plant was measured in centimeters from base of the stem to tip of the growing point with scale.

3.7.1.2 *Stem thickness (Girth)*

Girth of the stem was measured with tape at base of the plant above ground level and expressed in centimeters.

3.7.1.3 *Number of nodes*

Nodes present on both the stems of each plant were taken into consideration and their total was recorded as number of nodes per plant.

3.7.1.4 *Number of leaves*

The total number of leaves present in a plant were counted and recorded.

3.7.1.5 *Dry matter production*

Two plants at random outside the net plot area were carefully dug out with roots at 30, 60, 90, 120, 150, 180 and 210 days after planting and the leaves, stems and tuberous roots were separated and air dried. Their weights were recorded after drying in oven at 70°C for 72 hours and the mean dry weight of samples was recorded and expressed in t/ha.

3.7.2 Growth analysis parameters

3.7.2.1 *Leaf area (LA)*

The length and breadth of middle lobe for top, middle and bottom leaves in a plant were recorded at its widest point along with the number of lobes per leaf and

total number of intact green leaves and the leaf area per plant was computed adopting the linear measurement procedure suggested by Ramanujam and Indira (1978). Further, the results were expressed in cm².

3.7.2.2 Leaf area Index (LAI)

Leaf area index was calculated adopting the formula suggested by Williams (1946) as follows.

$$LAI = \frac{\text{Total leaf area per plant}}{\text{Ground area occupied by plant.}}$$

3.7.2.3 Net assimilation rate (NAR)

The NAR was calculated using the formula suggested by Williams (1946) and expressed in g m⁻² day⁻¹.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\ln L_2 - \ln L_1}{L_2 - L_1}$$

Where, W₁ and W₂ are whole plant dry weights (g) at times t₁ and t₂, respectively.

In L₁ and In L₂ are natural log values of leaf areas at times t₁ and t₂, respectively.

L₁ and L₂ are leaf area in m² at time t₁ and t₂, respectively

and t₁ and t₂ are the initial and final days of observation.

3.7.2.4 Crop growth rate (CGR)

Crop growth rate was calculated using the formula suggested by Buttery (1970) and expressed as g m⁻² day⁻¹.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where W_1 and W_2 are the initial and final dry weight of whole plant at the time t_1 and t_2 respectively, t_1 and t_2 are the initial and final days of observation and P is land area.

3.7.2.5 *Shoot/root ratio*

Fresh weight of shoot and its tuberous root was recorded and their ratio was computed and expressed as shoot/root ratio

3.7.3 *Yield parameters*

3.7.3.1 *Tuber length*

The length of storage tubers of five plants was measured and the mean was expressed in centimeter.

3.7.3.2 *Tuber diameter*

The maximum diameter of cassava tubers was measured for ten tubers using verniercalipers at random and the average was expressed as tuber diameter in centimeter.

3.7.3.3 *Fresh to dry weight of tubers*

Fresh to dry weight of tubers was estimated by taking 100 g of uniform size fresh tuber cut into small chips. Chips were air dried and then oven dried at 60°C till constant weight was obtained and their weight were recorded and expressed in percentage.

3.7.3.4 *Number of Tubers per plant*

The number of storage tubers of five plants of cassava were counted and the mean was expressed as number of tubers per plant.

3.7.3.5 *Tuber weight per plant*

The mean weight of fresh tubers from five selected plants was recorded in kilograms.

3.7.3.6 *Tuber yield per hectare*

Yield of fresh tubers harvested from the net plot area was assessed and expressed in tonnes/ha.

3.7.4 *Quality parameters*

3.7.4.1 *Starch content*

The procedure suggested by Mc Cready *et al.* (1950) was followed for the estimation of starch. One gram of the fresh tuber sample was ground in a pestle and mortar with 10 ml of 80 per cent ethanol and was kept aside for an hour. Later it was centrifuged at 3000 rpm for 15 minutes and the supernatant liquid was discarded and the residue was extracted thrice with 80 per cent ethanol and treated with 10 ml of 62 per cent perchloric acid for two hours. The content was then filtered and made up to 50 ml with distilled water. From this an aliquot of 0.2 ml was pipetted out into a test tube to which 4 ml of freshly prepared 0.1 per cent anthrone reagent (200 mg dissolved in 200 ml of concentrated sulphuric acid) was added slowly. It was kept in the ice bath for five minutes and the content was later shaken well and brought to room temperature; followed by immersion in warm water bath for ten minutes and cooling in tap water. The development of green colour was measured in spectrometer at 640 nm and the amount of sugars present was worked out from the standard graph prepared by plotting the absorbance to the corresponding known concentration of glucose. The results were expressed as percentage.

3.7.4.2 Hydrocyanin (HCN) content

The hydrocyanin content in tuber was estimated by the method described by Indira and Sinha (1969) and expressed as $\mu\text{g/g}$.

3.7.4.3 Crude fibre percentage

The percentage of crude fibre was estimated by the AOAC method (1975) and expressed as percentage on dry weight basis.

3.7.4.4 Cooking quality

Cooking quality was studied in terms of cooking time. The freshly harvested clean cassava tubers of uniform size and approximately of same weight were deskinning and the deskinning tubers were cut and dropped in boiling distilled water. Time of cooking was noted when the tuber pieces achieved transparent cooked appearance and when no more opaque starchy matter existed in the tuber pieces. Amount of water, type of water, type and size of vessels required were standardized before the investigative material was used.

3.7.5 Nutrient uptake

The whole plant samples collected to record the dry weights at harvest were separated into leaf, stem and tubers. These samples were ground into fine powder and were used to determine the nutrient contents (N, P and K). Nitrogen content was estimated using modified micro-kjeldahl method (AOAC, 1960), while phosphorous content was estimated by Venado molybdo phosphoric yellow colour method, suggested by Jackson (1967). Potassium was determined by flame photometer method as per the procedure given by AOAC (1975).

3.7.6 Economics

Gross and net returns/ha were computed considering the current market price of inputs and produce. Benefit cost ratio was worked out for different treatments by dividing the gross returns by cost of cultivation.

3.7.7 Statistical analysis

The data on various characters studied during the course of investigation was statistically analyzed as per the procedures outlined by Panse and Sukhatme (1978). Critical differences were worked out at five per cent probability level, provided the treatment differences were found significant in the 'F' test and if the treatments were observed non-significant in the 'F' test, the symbol 'NS' was indicated. Correlation studies were determined for yield and its attributing characters. The test of significance of correlation was carried out by referring to the tables of Fisher and Yates (1963).

Chapter IV

Results

CHAPTER IV

RESULTS

Cassava (*Manihot esculenta* Crantz) has its importance in tropical agriculture due to its drought tolerance, wide flexibility to adverse soil, nutrient management conditions and time of harvest. The crop is grown in sandy loams with inherent low fertility under uncertain rains as well as under irrigated conditions, wherever bore wells are available, in the local tracts comprising of upland areas of East Godavari district in Andhra Pradesh. Supply of nutrients to the long duration crop like cassava and enrichment of the soil nutrient status are important issues in cassava production. However, systematic studies on the response of cassava to nutrient application under rainfed and irrigated conditions are lacking, in spite of considerable area to an extent of 21,500 hectares being under the crop in Andhra Pradesh. In this context, the present investigation "Integrated nutrient management for cassava" was undertaken. The experiments were conducted separately under rainfed and irrigated conditions for two years during 2002-03 and 2003-04 and data on several aspects of cassava plant growth and development were recorded and subjected to statistical analysis. The results of these experiments are presented hereunder.

4.1 RAINFED EXPERIMENT

Results of the studies on effect of integrated nutrient management in cassava with regard to growth, yield, quality, nutrient uptake and economics of cultivation under rainfed conditions during 2002-03 and 2003-04 are presented in Tables 1 to 17.



4.1.1 Plant height

The results are presented in Table 1. An increase in plant height was observed from 21.80 cm to 104.02 cm during 2002-03; and from 22.18 to 122.86 cm during 2003-04 with an increase in the crop age from 30 DAP to 210 DAP. Further, greater plant height was in general observed at all the crop growth stages studied during 2003-04, compared to 2002-03.

The application of farm yard manure, vermicompost, green manure and the bio-fertilizer, *Azospirillum* in combination with full, 2/3 and 1/2 dose of recommended NPK inorganic fertilizers did not exhibit any significant effect on plant height at 30 DAP and the treatments studied were observed to be on a par with each other. However, significant differences were noticed among the treatments for plant height at all other growth stages studied during both the years of investigation.

At 60 DAP, T7 had recorded highest plant height during both the years of study 2002-03 (41.97 cm) and 2003-04 (47.43 cm). The treatments, T6 (39.23 cm) and T8 (38.37 cm) during 2002-03; and T3 (44.81 cm), T4 (41.03 cm), T6 (42.03 cm) and T8 (45.07 cm) during 2003-04 were observed to be statistically on a par with the T7 treatment. Further, lowest plant height was recorded for T13 treatment during both the years of study (31.90 cm during 2002-03 and 32.27 cm during 2003-04).

During 2002-03, significantly greater plant height was recorded by T7 treatment (68.82 cm) at 90 DAP compared to other treatments, while T13 (43.52 cm), T1 (45.87 cm) and T10 (48.77 cm) treatments had recorded lowest plant height. During 2003-04 also, T7 treatment had recorded highest plant height

1 : Plant height (cm) as influenced by integrated nutrient management in cassava under rainfed conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAF			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	-FYM)	20.43	19.57	20.00	32.60	33.37	32.98	45.87	56.17	51.02	76.17	89.34	82.75	83.95	93.83	88.74	87.96	95.44	91.70	92.23	97.94
-FYM+AZOS)	21.96	22.40	22.18	34.70	36.57	35.63	53.76	69.27	61.51	83.88	108.13	96.01	93.14	114.22	103.68	98.49	120.61	109.55	101.59	124.44	113.02
DF+FYM+AZOS)	23.09	23.73	23.41	36.20	44.81	40.50	60.82	76.37	68.59	87.83	120.07	103.95	97.64	125.42	111.38	105.19	129.79	117.49	107.98	135.87	121.92
DF+FYM+AZOS)	23.09	23.03	23.06	34.57	41.03	37.80	58.19	74.93	66.56	87.28	115.65	101.46	95.35	120.60	107.98	104.79	126.94	115.86	110.44	131.97	121.21
DF+FYM+AZOS)	21.49	22.10	21.80	33.80	33.43	33.62	55.02	66.37	60.69	79.16	103.74	91.45	88.46	109.35	98.90	95.16	117.77	106.46	98.04	110.95	104.49
-VC)	22.44	23.70	23.07	39.23	42.03	40.63	61.30	75.67	68.48	88.87	116.31	102.59	98.83	122.89	110.86	106.91	125.41	116.16	113.63	132.31	122.97
-VC+AZOS)	23.17	25.29	24.23	41.97	47.43	44.70	68.82	83.62	76.22	93.99	126.37	110.18	106.97	130.47	118.72	113.71	136.38	125.04	117.71	141.98	129.85
DF+VC+AZOS)	22.60	24.30	23.45	38.37	45.07	41.72	61.45	80.47	70.96	90.30	121.09	105.69	104.08	126.86	115.47	99.46	124.52	111.99	107.65	128.11	117.88
DF+VC+AZOS)	21.50	22.60	22.05	36.33	37.63	36.98	56.25	70.40	63.33	80.54	113.02	96.78	90.15	120.51	105.33	92.71	108.47	100.59	95.13	113.12	104.13
+GM)	21.09	20.43	20.76	32.47	33.17	32.82	48.77	64.98	56.87	80.52	95.55	88.03	84.84	102.85	93.85	92.71	108.47	100.59	100.49	117.04	108.76
+GM+AZOS)	21.60	21.20	21.40	34.80	34.03	34.42	50.61	76.70	63.66	85.75	99.21	92.48	86.78	107.97	97.37	95.11	114.80	104.95	98.32	114.61	106.46
DF+GM+AZOS)	20.60	20.63	20.62	32.95	33.39	33.17	50.20	69.80	60.00	86.36	98.64	92.50	86.36	105.89	96.13	94.08	110.54	102.31	98.32	114.61	106.46
DF+GM+AZOS)	20.29	19.37	19.83	31.90	32.27	32.08	43.52	63.40	53.46	79.10	93.42	86.26	82.68	93.51	88.10	90.63	106.69	98.66	93.69	112.75	103.22
Mean	21.80	22.18		35.38	38.02		54.97	71.40		84.60	107.73		92.25	113.87		99.48	119.08		104.02	122.86	
	0.99	1.23		1.54	2.32		1.90	2.58		2.03	2.53		2.09	3.73		1.32	3.19		1.78	2.87	
5)	NS	NS		4.50	6.77		5.54	7.53		5.91	7.39		6.11	8.11		3.84	9.32		5.20	8.37	

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(83.62 cm) and the treatments, T11 (76.70 cm) and T3 (76.37 cm) were observed to be statistically on a par with the T7 treatment. Lowest plant height was recorded for T1 treatment (56.17 cm) during the year 2003-04. Further, T13 treatment had recorded plant height (63.40 cm) statistically on a par with T1 treatment during 2003-04.

At 120 days after planting, T7 treatment had recorded highest plant height during both 2002-03 (93.99 cm) and 2003-04 (126.37 cm) years. Further, T6 treatment (88.87 cm) during 2002-03; and T3 (120.07 cm) and T8 (121.09 cm) treatments during 2003-04 had recorded the plant height which were on a par with T7 treatment. In contrast, T1 treatment had recorded lowest plant height during both the years of study 2002-03 (76.17 cm) and 2003-04 (89.34 cm).

At 150 DAP also; T7 had recorded highest plant height during both 2002-03 (106.97 cm) and 2003-04 (130.47 cm). The treatments, T8 (104.08 cm) during 2002-03; and T3 (125.12 cm), T6 (122.89 cm) and T8 (126.86 cm) during 2003-04 had recorded plant height on a par with T7 treatment. Further, lowest plant height was recorded by T13 treatment during both the years 2002-03 (82.68 cm) and 2003-04 (93.51 cm).

At 180 DAP, significantly greater plant height was recorded by T7 treatment (113.71 cm) during 2002-03, compared to other treatments, while lowest plant height was recorded by T1 treatment (87.96 cm). During 2003-04 also, T7 treatment had recorded highest plant height (136.38 cm) and was observed to be on a par with T3 (129.79 cm) and T8 (130.68 cm) treatments. Further, T1 treatment had recorded lowest plant height (95.44 cm) during 2003-04.

At 210 DAP, highest plant height was recorded by T7 treatment (117.71 and 141.98 cm), while lowest plant height was recorded by T1 treatment (92.23 and 97.94 cm) during both 2002-03 and 2003-04, respectively. Further, the treatments, T6 (113.63 cm) and T8 (115.31 cm) during 2002-03; and T3 (135.87 cm) and T8 (136.13 cm) during 2003-04 have recorded plant height which were on a par with T7 treatment.

4.1.2 Stem girth

The results are presented in Table 2. An increase in stem girth from 2.58 to 7.38 cm during 2002-03; and from 2.38 to 7.85 cm during 2003-04 was observed in the present investigation with an increase in the crop age from 30 DAP to 210 DAP. Further, greater stem girth was in general noticed during 2003-04, compared to 2002-03 at 60, 90, 120 and 210 DAP.

The application of farm yard manure, vermicompost, green manure and bio-fertilizer, *Azospirillum* in combination with different doses of recommended NPK inorganic fertilizers was observed to result in non-significant effect on stem girth at 30, 60, and 90 DAP during both 2002-03 and 2003-04. However, significant differences were noticed among the treatments for stem girth at 120, 150, 180 and 210 DAP during both the years of investigation.

At 120 DAP; highest stem girth was recorded by T7 treatment, (6.55 cm and 7.27 cm), while lowest was recorded by T1 treatment (4.63 cm and 5.10 cm) during both 2002-03 and 2003-04, respectively. Further, the treatments T6 (5.96 cm), T8 (6.13 cm) and T9 (6.04 cm) during 2002-03; T2 (6.03 cm), T3 (6.70 cm), T4

Table 2 : Stem girth (cm) as influenced by integrated nutrient management in cassava under rainfed conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	2.37	2.07	2.22	2.60	2.67	2.63	3.47	4.17	3.82	4.63	5.10	4.87	5.53	5.27	5.40	6.17	6.27	6.22	6.40	6.83
T ₂ (RDF+FYM)	2.60	2.40	2.50	2.67	3.07	2.87	3.73	4.52	4.13	5.21	6.03	5.62	6.13	6.39	6.26	6.50	7.40	6.95	6.77	7.79	7.28
T ₃ (RDF+FYM+AZOS)	2.80	2.77	2.78	2.83	3.60	3.22	3.77	5.37	4.57	5.68	6.70	6.19	7.07	7.23	7.17	7.15	7.93	7.54	7.30	8.28	7.79
T ₄ (1/3 RDF+FYM+AZOS)	2.77	2.70	2.73	2.97	3.43	3.20	3.80	5.03	4.42	5.60	6.43	6.02	6.63	6.13	6.68	7.00	7.57	7.29	7.17	8.17	7.67
T ₅ (1/2 RDF+FYM+AZOS)	2.73	2.10	2.42	2.87	2.87	2.87	3.53	4.55	4.04	5.50	5.47	5.48	6.57	6.40	6.48	6.80	7.30	7.05	7.03	7.85	7.44
T ₆ (RDF+VC)	2.63	2.53	2.58	3.07	3.60	3.33	3.89	5.35	4.62	5.96	6.88	6.42	7.37	7.30	7.33	7.57	8.18	7.87	8.17	8.25	8.21
T ₇ (RDF+VC+AZOS)	2.90	2.90	2.90	3.20	3.80	3.50	4.00	5.97	4.98	6.55	7.27	6.91	7.90	7.54	7.72	8.11	8.31	8.21	8.50	8.53	8.51
T ₈ (1/3 RDF+VC+AZOS)	2.67	2.76	2.71	2.70	3.73	3.22	3.77	5.74	4.75	6.13	7.04	6.59	7.77	7.43	7.60	8.05	8.27	8.16	8.20	8.40	8.30
T ₉ (1/2 RDF+VC+AZOS)	2.57	2.47	2.52	2.67	3.12	2.89	3.73	5.25	4.49	6.04	6.73	6.38	7.10	7.24	7.17	7.48	7.68	7.58	7.51	8.10	7.81
T ₁₀ (RDF+GM)	2.33	2.03	2.18	2.23	2.70	2.47	3.20	4.43	3.82	5.48	5.43	5.46	6.67	6.62	6.14	6.80	6.98	6.89	7.13	7.27	7.20
T ₁₁ (RDF+GM+AZOS)	2.50	2.20	2.35	2.37	2.87	2.62	3.77	5.39	4.58	5.63	6.07	5.85	7.20	6.63	6.92	7.27	7.31	7.29	7.53	7.89	7.71
T ₁₂ (1/3 RDF+GM+AZOS)	2.43	2.10	2.27	2.35	2.79	2.57	3.67	5.20	4.43	5.36	6.03	5.70	7.23	6.50	6.87	7.20	7.20	7.20	7.37	7.64	7.50
T ₁₃ (1/2 RDF+GM+AZOS)	2.30	1.93	2.12	2.50	2.63	2.57	3.44	4.40	3.92	5.21	5.37	5.29	6.27	5.70	5.98	6.32	6.40	6.36	6.80	7.10	6.95
General Mean	2.58	2.38	2.48	2.69	3.14	2.91	3.67	5.03	4.30	5.61	6.20	5.82	6.88	6.62	6.75	7.11	7.45	7.11	7.38	7.85	7.50
S.E.m.	0.18	0.20	0.19	0.12	0.23	0.18	0.18	0.30	0.29	0.29	0.43	0.32	0.32	0.31	0.31	0.18	0.27	0.24	0.24	0.25	0.25
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.84	1.24	0.93	0.93	0.91	0.54	0.54	0.78	0.71	0.71	0.72	0.72

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(6.43 cm), T6 (6.88 cm), T8 (7.04 cm), T9 (6.73 cm), T11 (6.07 cm) and T12 (6.03 cm) during 2003-04 had recorded stem girth on a par with T7 treatment.

Highest stem girth at 150 DAP was recorded by T7 treatment (7.90 cm and 7.54 cm), while lowest was recorded by T1 treatment (5.53 cm and 5.27 cm) during both 2002-03 and 2003-04, respectively. Further, the treatments T3 (7.07 cm), T6 (7.37 cm), T8 (7.77 cm), T9 (7.10 cm), T11 (7.20 cm) and T12 (7.23 cm) during 2002-03; and T3 (7.28 cm), T4 (6.73 cm), T6 (7.30 cm), T8 (7.43 cm), T9 (7.24 cm) and T11 (6.63 cm) during 2003-04 had recorded stem girth which were on a par with T7 treatment.

At 180 DAP, highest stem girth was recorded by T7 (8.11 cm) and T6 (7.57 cm) treatments, while lowest stem girth was recorded by T1 (6.17 cm), T2 (6.50 cm) and T13 (6.32 cm) treatments during 2002-03. Further, the treatment T7 (8.31 cm) had also recorded highest stem girth during 2003-04 and was statistically on a par with the stem girth recorded by T3 (7.93 cm), T4 (7.57 cm), T6 (8.18 cm), T8 (8.27 cm) and T9 (7.86 cm) treatments.

Highest stem girth at 210 DAP was also recorded by T7 treatment during both 2002-03 (8.50 cm) and 2003-04 (8.53 cm). Further, it was observed to be on a par with the stem girth recorded by T6 (8.17 cm) and T8 (8.20 cm) treatments during 2002-03; and T3 (8.28 cm), T4 (8.17 cm), T5 (7.85 cm), T6 (8.25 cm), T8 (8.40 cm), T9 (8.10 cm) and T11 (7.89 cm) treatments during 2003-04. Lowest stem girth was however, recorded by T1 treatment during 2002-03 (6.40 cm) and 2003-04 (6.83 cm).

4.1.3 Number of nodes

The results are presented in Table 3. Number of nodes was noticed to increase from 21.69 to 106.37 during 2002-03 and from 22.76 to 127.03 during 2003-04 with an increase in the crop age from 30 to 210 DAP. Further, greater number of nodes per plant were in general observed during 2003-04, compared to 2002-03 at the different growth stages studied, except at 60 DAP.

The INM treatments imposed in the present investigation did not exhibit any significant influence on the number of nodes per plant at 30 DAP during 2002-03 and 2003-04. However, significant differences were observed among the treatments at 60, 90, 120, 150 and 210 DAP during both the years of investigation.

At 60 DAP; highest number of nodes per plant was recorded by T7 treatment (48.57 and 49.80), while lowest was noticed by T13 treatment (38.00 and 32.97) during 2002-03 and 2003-04, respectively. Further, the treatments, T3 (46.97), T6 (45.93), T8 (46.10) and T9 (45.50) during 2002-03; and T3 (45.17), T6 (46.37) and T8 (47.73) during 2003-04 were observed to be on a par with the best treatment (T7).

At 90 DAP; the highest number of nodes per plant was recorded by T7 treatment (76.47), while lowest was recorded by T13 treatment (52.30) during 2002-03. However, T6 (71.70) and T8 (71.51) treatments were found to be on a par with T7 treatment. During 2003-04 also, T7 treatment had recorded highest number of nodes per plant (100.42) and was found to be on a par with T8 (98.22), while lowest number of nodes was recorded for T1 treatment (65.98) during the year.

3 : Number of nodes per plant as influenced by integrated nutrient management in cassava under rainfed conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP			
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	
-FYM)	21.05	21.85	21.45	40.70	35.04	37.87	57.24	65.98	61.61	81.14	92.80	86.97	88.27	96.13	92.20	91.56	98.85	95.20	94.05	102.56	98.30	
-FYM+AZOS)	22.49	22.87	22.68	43.87	40.13	42.00	60.53	86.37	73.45	88.60	115.27	101.93	98.47	122.55	110.52	101.46	125.78	113.62	104.85	130.72	117.78	
-FYM+AZOS)	23.30	25.92	24.61	46.97	45.17	46.07	65.03	93.00	79.02	91.25	124.54	107.89	103.77	129.44	116.60	108.08	134.60	121.34	110.71	139.69	125.20	
DF+FYM+AZOS)	22.00	24.30	23.15	42.92	42.97	42.94	60.97	89.00	74.98	87.03	119.66	103.34	98.20	123.22	110.71	107.29	127.15	117.22	112.17	133.87	123.02	
DF+FYM+AZOS)	22.20	21.50	21.85	43.73	37.77	40.75	56.07	85.32	70.69	85.81	110.95	98.38	97.02	117.39	107.21	98.35	123.07	110.71	105.81	126.04	115.92	
-VC)	22.78	24.07	23.42	45.93	46.37	46.15	71.70	91.53	81.62	92.33	120.20	106.26	110.53	124.08	117.30	110.49	128.10	119.30	114.31	134.73	124.52	
-VC+AZOS)	23.60	26.37	24.98	48.57	49.80	49.18	76.47	100.42	88.44	96.89	132.51	114.70	115.16	136.79	125.98	115.66	142.57	129.11	120.76	145.22	132.99	
DF+VC+AZOS)	22.80	25.43	24.12	46.10	47.73	46.92	71.51	98.22	84.86	92.77	126.09	109.43	106.84	132.24	119.54	110.70	136.47	123.59	110.75	140.09	125.42	
DF+VC+AZOS)	20.70	21.67	21.18	45.50	41.27	43.38	62.20	86.35	74.28	90.56	118.67	104.62	103.36	122.25	112.81	103.61	126.61	115.11	109.55	132.25	120.90	
+GM)	19.73	20.46	20.10	38.80	33.60	36.20	53.87	83.32	68.59	83.93	96.99	90.46	85.67	104.53	95.10	95.10	110.43	102.77	97.95	114.57	106.26	
+GM+AZOS)	20.73	20.57	20.65	40.37	34.22	37.30	55.07	88.47	71.77	87.93	102.66	95.30	89.09	111.15	100.12	98.49	118.45	108.47	104.06	121.94	113.00	
RDF+GM+AZOS)	20.50	20.53	20.52	38.97	33.97	36.47	55.20	87.03	71.12	88.07	101.90	94.98	87.94	107.24	97.59	96.40	114.59	105.50	100.83	117.59	109.21	
RDF+GM+AZOS)	20.07	20.30	20.18	38.00	32.97	35.48	52.30	82.63	67.47	84.10	94.47	89.29	85.04	102.26	93.65	93.73	109.81	101.77	96.99	112.09	104.54	
Mean	21.69	22.76		43.11	40.08		61.40	87.51		88.49	112.05		97.64	117.64		102.38	122.81		106.37	127.03		
5)	1.31	1.05		1.54	1.89		1.78	1.99		1.92	2.36		1.50	3.30		1.29	2.51		1.50	2.60		
	NS	NS		4.48	5.52		5.20	5.81		5.62	6.89		4.37	9.63		3.77	7.33		4.39	7.58		

At 120 DAP, highest number of nodes per plant was recorded for T7 treatment (96.89 and 132.51), while lowest number was recorded by T1 treatment (81.41 and 92.80) during 2002-03 and 2003-04, respectively, Further, the treatments, T6 (92.33) and T8 (92.77) during 2002-03; and T8 (126.09) during 2003-04 were found to be on a par with T7 treatment.

At 150 DAP; highest number of nodes per plant was recorded by T7 treatment for both 2002-03 (115.16) and 2003-04 (136.79) while lowest was recorded for T13 treatment (85.04) during 2002-03; and T1 treatment (96.13) during 2003-04. Further, the treatments T3 (129.44) and T8 (132.24) were found to be statistically on a par with T7 treatment during 2003-04.

Highest number of nodes per plant was recorded by T7 treatment at 180 (115.66 and 142.57, respectively) and 210 (120.76 and 145.22, respectively) DAP for both 2002-03 and 2003-04 years of investigation, while lowest number of nodes was recorded by T1 treatment at 180 (91.56 and 98.85, respectively) and 210 (94.05 and 102.56, respectively) DAP for both 2002-03 and 2003-04. Further, the treatment T8 at 180 DAP (136.47); and T3 (139.69) and T8 (140.04) at 210 DAP were found to be on a par with T7 treatment during 2003-04.

4.1.4 Number of leaves

Results on the effect of INM treatments on number of leaves per plant at different growth stages are presented in Table 4. The number of leaves were observed to increase from 21.02 to 84.93 during 2002-03 and from 21.66 to 99.44 during 2003-04 with an increase in the crop age from 30 to 150 DAP. The decrease in the leaf number was observed from 76.51 to 67.57 during 2002-03, and from

Table 4 : Number of leaves per plant as influenced by integrated nutrient management in cassava under rainfed conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	1 (RDF)	20.10	18.48	19.29	28.60	26.93	27.77	40.90	48.10	44.50	57.00	74.39	69.85	74.21	82.70	74.30	54.75	58.24	56.50	43.69	49.41
2 (RDF+FYM)	20.83	22.49	21.66	30.70	32.80	31.75	46.10	56.40	51.25	62.01	92.40	79.57	87.47	97.12	89.93	72.13	81.62	76.88	60.42	64.11	62.27
3 (RDF+FYM+AZOS)	21.09	23.19	22.14	32.37	40.27	36.32	48.30	66.70	57.50	67.83	103.89	89.28	91.55	110.73	97.72	85.91	90.76	88.34	73.49	73.74	73.61
4 (² / ₃ RDF+FYM+AZOS)	21.80	22.83	22.32	32.33	35.93	34.13	50.42	59.97	55.19	62.13	98.45	83.95	90.33	105.78	94.39	79.70	86.68	83.19	68.59	69.65	69.12
5 (¹ / ₂ RDF+FYM+AZOS)	21.47	21.57	21.52	29.77	30.60	30.18	46.70	55.87	51.28	59.81	88.12	76.94	86.42	94.08	87.27	77.04	78.58	77.81	65.34	62.42	63.88
6 (RDF+VC)	22.72	23.11	22.92	33.83	35.67	34.75	52.73	63.67	58.20	70.08	101.04	86.87	87.62	103.65	94.33	81.86	90.52	86.19	72.82	72.27	72.54
7 (RDF+VC+AZOS)	22.53	24.60	23.57	37.02	41.10	39.06	54.77	73.83	64.30	72.13	111.06	96.09	92.85	120.05	101.95	87.80	99.06	93.43	79.87	81.80	80.83
8 (² / ₃ RDF+VC+AZOS)	22.00	23.46	22.73	35.08	37.43	36.26	49.70	67.63	58.67	66.77	106.40	88.42	89.51	110.07	97.96	83.68	93.46	88.57	75.09	76.94	76.02
9 (¹ / ₂ RDF+VC+AZOS)	20.80	22.73	21.76	33.04	34.33	33.69	45.18	62.37	53.77	56.67	99.34	81.27	81.94	105.87	90.64	77.07	86.87	81.97	70.70	70.99	70.85
10 (RDF+GM)	19.73	20.13	19.93	27.55	27.87	27.71	41.42	51.40	46.41	58.61	82.45	74.00	81.67	89.39	82.06	71.58	77.78	74.68	66.13	63.87	65.00
11 (RDF+GM+AZOS)	20.63	20.31	20.47	31.93	28.80	30.37	43.67	53.27	48.47	62.43	88.11	79.58	84.13	96.74	86.12	78.75	83.30	81.02	70.77	69.81	70.29
12 (² / ₃ RDF+GM+AZOS)	19.50	20.18	19.84	31.60	28.93	30.27	42.90	52.53	47.72	61.97	86.78	78.18	79.55	94.39	83.17	74.39	80.61	77.50	70.33	67.08	68.70
13 (¹ / ₂ RDF+GM+AZOS)	20.07	18.53	19.30	28.17	26.53	27.35	39.43	51.40	45.42	56.77	82.30	71.40	76.80	86.04	79.55	69.95	76.92	73.44	61.20	61.01	61.10
General Mean	21.02	21.66		31.69	32.86		46.32	58.70		62.63	93.44		84.93	99.34		76.51	83.41		67.57	67.93	
S.E.M.	0.78	0.83		1.64	2.09		1.35	2.24		1.51	2.25		1.44	2.30		1.58	2.36		1.68	2.20	
D.F.(0.05)	NS	NS		4.78	6.09		3.95	6.55		4.40	6.56		4.19	8.43		4.60	6.89		4.91	6.44	

83.41 to 67.93 during 2003-04 with an increase in the crop age from 180 to 210 DAP. Further, greater number of leaves per plant were in general noticed during 2003-04, compared to 2002-03 at all the growth stages studied.

The INM treatments effected in the present investigation were observed to be non-significant with regards to their influence on number of leaves per plant at 30 DAP during 2002-03 and 2003-04. However, a significant influence of the treatments was observed at all other growth stages studied.

At 60 DAP, T7 treatment had recorded highest number of leaves per plant during 2002-03 (37.02) and 2003-04 (41.10). The treatments, T3 (32.37), T4 (32.33), T6 (33.83), T8 (35.08) and T9 (33.04) during 2002-03; and T3 (40.27), T4 (35.93), T6 (35.67) and T8 (37.43) during 2003-04 have also recorded number of leaves per plant on a par with T7 treatment. However, T10 during 2002-03 (27.55) and T13 during 2003-04 (26.53) had recorded lowest number of leaves per plant.

At 90 DAP, T7 treatment had recorded highest number of leaves per plant during both 2002-03 (54.77) and 2003-04 (73.83). The treatment, T6 (52.73) during 2002-03 and T8 (67.63) during 2003-04 have also recorded number of leaves per plant on a par with T7 treatment. Further, lowest number of leaves per plant was recorded by T13 treatment (39.43) during 2002-03 and T1 treatment (48.10) during 2003-04.

The treatment, T7 had also recorded highest number of leaves per plant at 120 DAP during both 2002-03 (72.13) and 2003-04 (111.06). Further, the treatments, T3 (67.83) and T6 (70.08) were observed to be on a par with T7

treatment during 2002-03. Lowest number of leaves per plant was recorded by the treatment T9 (56.67) during 2002-03 and T1 (74.39) during 2003-04.

At 150 DAP also, T7 treatment had recorded highest number of leaves per plant during 2002-03 (92.85) and 2003-04 (120.05). The treatments, T3 (91.55), T4 (90.33) and T8 (89.51) during 2002-03 have also recorded number of leaves per plant on a par with T7 treatment. Further, lowest leaves per plant were recorded by T1 treatment during both 2002-03 (74.21) and 2003-04 (82.70).

T7 treatment had also recorded highest number of leaves per plant at 180 DAP during 2002-03 (87.80) and 2003-04 (99.06). Further, the treatments, T3 (85.91) and T8 (83.68) during 2002-03; and T8 (93.46) during 2003-04 have recorded number of leaves per plant on a par with T7 treatment. Lowest number of leaves per plant was recorded by T1 treatment during both 2002-03 (54.75) and 2003-04 (58.24).

At 210 DAP, T7 treatment had recorded highest number of leaves per plant during 2002-03 (79.87) and 2003-04 (81.80). Further, T8 treatment had recorded number of leaves on a par with T7 treatment during both 2002-03 (75.09) and 2003-04 (76.94). Lowest number of leaves per plant was recorded by T1 treatment during both 2002-03 (43.69) and 2003-04 (49.41).

4.1.5 Leaf area

The results are presented in Table 5. An increase in leaf area plant (cm^2) with increase in the crop age was observed up to 150 days after planting during both years of investigation. However, at later growth stages, leaf area decreased with an increase in the crop age. Further, greater leaf area was in general observed during

Table 5 : Leaf area per plant (cm²) as influenced by integrated nutrient management in cassava under rainfed conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	1073	1002	1038	1739	1731	1735	6392	6998	6695	7646	9851	10042	9438	12438	9644	7666	8404	8035	6003	5614
T ₂ (RDF+FYM)	1116	1275	1196	1969	2291	2130	7156	8783	7970	9141	13316	12582	12808	16023	13062	10643	11208	10926	9812	10269	10041
T ₃ (RDF+FYM+AZOS)	1240	1319	1280	2276	3085	2680	8738	11157	9948	9635	17017	14213	13725	18792	15371	12606	13492	13049	11024	12009	11516
T ₄ (1/3 RDF+FYM+AZOS)	1263	1310	1287	2029	2889	2459	9271	9256	9264	9309	14089	13572	13560	17834	13825	12478	12566	12522	10942	9529	10236
T ₅ (1/2 RDF+FYM+AZOS)	1112	1195	1153	2025	2306	2165	7379	8361	7870	9365	12314	12364	12220	15364	12267	10852	11300	11076	8884	9366	9125
T ₆ (RDF+VC)	1293	1357	1325	2382	3150	2766	9413	9888	9650	10294	15735	13441	13409	16588	14572	11402	12531	11966	11216	11135	11176
T ₇ (RDF+VC+AZOS)	1427	1459	1443	2556	4184	3370	9614	11887	10750	11765	18147	17196	13526	22627	15836	13214	15302	14258	13052	13357	13205
T ₈ (1/3 RDF+VC+AZOS)	1306	1380	1343	2481	3565	3023	8681	11195	9938	10185	16212	14455	13558	18725	14885	12089	15080	13584	12991	12065	12528
T ₉ (1/2 RDF+VC+AZOS)	1168	1233	1201	1878	3183	2531	7496	9237	8367	8994	15270	13091	10635	17189	12953	10182	11813	10997	11621	10355	10988
T ₁₀ (RDF+GM)	946	1063	1005	1701	1818	1760	6975	7245	7110	8813	10932	11588	10489	14363	10711	8874	10439	9656	11340	9700	10520
T ₁₁ (RDF+GM+AZOS)	1117	1148	1133	1785	1953	1869	7119	7510	7315	9310	12890	12272	11454	15235	12172	10615	11921	11268	11619	11101	11360
T ₁₂ (1/3 RDF+GM+AZOS)	934	1054	994	1735	1889	1812	6470	7317	6893	9134	12285	11810	11293	14485	11789	8786	10763	9775	11422	10378	10900
T ₁₃ (1/2 RDF+GM+AZOS)	888	817	852	1674	1621	1647	6092	6526	6309	7896	10862	10426	9820	12956	10341	7743	8974	8359	8477	8788	8633
General Mean	1145	1201		2018	2590		7753	8874		9345	13763		11995	16355		10550	11830		10646	10282	
S.E.m	41	61		88	114		112	335		492	434		280	619		609	368		379	556	
C.D. (0.05)	120	178		258	333		328	978		1435	1268		816	1806		1777	1075		1107	1624	

2003-04, compared to 2002-03 at all the growth stages studied, except at 210 DAP. The application of INM treatments was also observed to exert a significant influence on the leaf area per plant at all the growth stages studied.

Among the treatments, T7 had consistently recorded highest leaf area/plant at all the growth stages during 2002-03 (1427 cm² at 30 DAP, 2556 cm² at 60 DAP, 9614 cm² at 90 DAP, 11765 cm² at 120 DAP, 13526 cm² at 150 DAP, 13214 cm² at 180 DAP and 13052 cm² at 210 DAP) and 2003-04 (1459 cm² at 30 DAP, 4184 cm² at 60 DAP, 11887 cm² at 90 DAP, 18147 cm² at 120 DAP, 22627 cm² at 150 DAP, 15302 cm² at 180 DAP and 13357 cm² at 210 DAP), with the exception of 150 DAP during 2002-03, where in T3 treatment had recorded highest leaf area per plant (13725 cm²). The treatments, T6 (2382 cm²) and T8 (2481 cm²) at 60 DAP; T6 (9413 cm²) at 90 DAP; T4 (13560 cm²), T6 (13409 cm²), T7 (13526 cm²) and T8 (13558 cm²) at 150 DAP; T3 (12606 cm²), T4 (12478 cm²) and T8 (12089 cm²) at 180 DAP; and T8 (12991 cm²) at 210 DAP had recorded leaf area per plant on a par with T7 treatment during 2002-03; while T3 (1319 cm²), T4 (1310 cm²), T6 (1357 cm²) and T8 (1380 cm²) at 30 DAP; T3 (11157 cm²) and T8 (11195 cm²) at 90 DAP; T3 (17017 cm²) at 120 DAP; T8 (15080 cm²) at 180 DAP; and T3 (12009 cm²) and T8 (12065 cm²) at 210 DAP had recorded leaf area on a par with the best treatment during 2003-04. However, lowest leaf area was recorded by T13 treatment at 30, 60 and 90 DAP during 2002-03 (888 cm², 1674 cm² and 6092 cm², respectively) and 2003-04 (817 cm², 1621 cm² and 6526 cm², respectively), while T1 treatment had recorded lowest leaf area per plant at 120, 150, 180 and 210 DAP

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during 2002-03 (7646 cm², 9438 cm², 7666 cm² and 6003 cm², respectively) and 2003-04 (9851 cm², 12431 cm², 8404 cm² and 5614 cm², respectively).

4.1.6 Leaf area index

The experimental results are presented in Table 6. An increase in leaf area index was observed with an increase in the crop age up to 150 DAP. However, at later stages of the crop growth (180 and 210 DAP) a decrease in the leaf area index was noticed with increase in the crop age due to senescence of leaves. Further, leaf area index was in general observed to be higher during 2003-04, compared to 2002-03 at different growth stages studied, with the exception of leaf area index at 210 DAP.

The application of various INM treatments was noticed to result in a significant influence on leaf area index per plant at all the crop growth stages studied. T7 treatment had recorded highest leaf area index at 30 (0.176), 60 (0.316), 90 (1.190), 120 (1.450), 150 (1.670), 180 (1.630) and 210 (1.610) DAP during 2002-03; and 30 (0.180), 60 (0.517), 90 (1.470), 120 (2.240), 150 (2.790), 180 (1.890) and 210 (1.650) DAP during 2003-04, while T3 treatment (1.690) had recorded highest leaf area index at 150 DAP during 2002-03. Further, the treatments T8 (0.161) at 30 DAP; T6 (0.294) and T8 (0.306) at 60 DAP; T6 (1.160) at 90 DAP; T4 (1.670), T6 (1.660), T7 (1.670) and T8 (1.670) at 150 DAP; T3 (1.560), T4 (1.540), and T8 (1.490) at 180 DAP; and T8 (1.600) at 210 DAP during 2002-03; and T3 (0.163), T4 (0.162), T6 (0.168) and T8 (0.170) at 30 DAP; T3 (1.380) and T8 (1.380) at 90 DAP; T3 (2.100) at 120 DAP; T8 (1.860) at 180 DAP; and T3 (1.480) and T8 (1.490) at 210 DAP during 2003-04 had recorded leaf area index

Table 6 : Leaf area index as influenced by integrated nutrient management in cassava under rainfed conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	0.132	0.124	0.128	0.215	0.213	0.214	0.789	0.864	0.827	0.944	1.220	1.240	1.160	1.540	1.190	0.947	1.040	0.992	0.741	0.693
T ₂ (RDF+FYM)	0.138	0.157	0.148	0.243	0.283	0.263	0.883	1.080	0.984	1.130	1.640	1.550	1.580	1.980	1.610	1.310	1.380	1.350	1.210	1.270	1.240
T ₃ (RDF+FYM+AZOS)	0.153	0.163	0.158	0.281	0.381	0.331	1.080	1.380	1.230	1.190	2.100	1.750	1.690	2.320	1.900	1.560	1.670	1.610	1.360	1.480	1.420
T ₄ (1/3 RDF+FYM+AZOS)	0.156	0.162	0.159	0.250	0.357	0.304	1.140	1.140	1.140	1.150	1.740	1.680	1.670	2.200	1.710	1.540	1.550	1.550	1.350	1.180	1.260
T ₅ (1/2 RDF+FYM+AZOS)	0.137	0.148	0.143	0.250	0.284	0.267	0.911	1.030	0.972	1.160	1.520	1.530	1.510	1.900	1.510	1.340	1.400	1.370	1.100	1.160	1.130
T ₆ (RDF+VC)	0.160	0.168	0.164	0.294	0.389	0.342	1.160	1.220	1.190	1.270	1.940	1.660	1.660	2.050	1.800	1.410	1.550	1.480	1.380	1.370	1.380
T ₇ (RDF+VC+AZOS)	0.176	0.180	0.178	0.316	0.517	0.416	1.190	1.470	1.330	1.450	2.240	2.120	1.670	2.790	1.950	1.630	1.890	1.760	1.610	1.650	1.630
T ₈ (1/3 RDF+VC+AZOS)	0.161	0.170	0.166	0.306	0.440	0.373	1.070	1.380	1.230	1.260	2.000	1.780	1.670	2.310	1.840	1.490	1.860	1.680	1.600	1.490	1.550
T ₉ (1/2 RDF+VC+AZOS)	0.144	0.152	0.148	0.232	0.393	0.313	0.925	1.140	1.030	1.110	1.880	1.620	1.310	2.120	1.600	1.260	1.460	1.360	1.440	1.280	1.360
T ₁₀ (RDF+GM)	0.117	0.131	0.124	0.210	0.224	0.217	0.861	0.894	0.878	1.090	1.350	1.430	1.290	1.770	1.320	1.100	1.290	1.190	1.400	1.200	1.300
T ₁₁ (RDF+GM+AZOS)	0.138	0.142	0.140	0.220	0.241	0.231	0.879	0.927	0.903	1.150	1.590	1.520	1.410	1.880	1.500	1.310	1.470	1.390	1.430	1.370	1.400
T ₁₂ (1/3 RDF+GM+AZOS)	0.115	0.130	0.123	0.214	0.233	0.224	0.799	0.903	0.851	1.130	1.520	1.460	1.390	1.790	1.460	1.090	1.330	1.210	1.410	1.280	1.350
T ₁₃ (1/2 RDF+GM+AZOS)	0.110	0.101	0.105	0.207	0.200	0.204	0.752	0.806	0.779	0.975	1.340	1.290	1.210	1.600	1.280	0.956	1.110	1.030	1.050	1.080	1.070
General Mean	0.141	0.148		0.249	0.320		0.957	1.096		1.154	1.699		1.481	2.019		1.302	1.461		1.314	1.269	
S.E.m	0.005	0.008		0.011	0.014		0.014	0.041		0.061	0.054		0.035	0.089		0.075	0.046		0.047	0.069	
C.D (0.05)	0.015	0.022		0.032	0.041		0.041	0.121		0.177	0.156		0.101	0.259		0.219	0.133		0.137	0.200	

on a par with T7 treatment. However, lowest leaf area index was recorded by T13 treatment at 30 (0.110 and 0.101), 60 (0.207 and 0.200), and 90 (0.752 and 0.806) DAP during 2002-03 and 2003-04, respectively; while T1 treatment had recorded lowest leaf area index at 120 (0.944 and 1.220), 150 (1.160 and 1.540), 180 (0.947 and 1.040) and 210 (0.741 and 0.693) DAP during 2002-03 and 2003-04, respectively.

4.1.7 Total dry matter production

The results are presented in Table 7. An increase in total dry matter production was observed with an increase in the crop age. Further, total dry matter production was noticed to be higher during 2003-04, compared to 2002-03 at all the growth stages. The effect of different INM treatments was also observed to be significant at all the growth stages. Highest total dry matter production was recorded uniformly in T7 treatment at 30 (0.21 t/ha), 60 (0.74 t/ha), 90 (1.56 t/ha), 120 (4.39 t/ha), 150 (7.57 t/ha) and 180 (9.93 t/ha) DAP during 2002-03; and 30 (0.23 t/ha), 60 (0.85 t/ha), 90 (1.78 t/ha), 120 (5.01 t/ha), 150 (8.64 t/ha) and 180 (11.34 t/ha) DAP during 2003-04. T8 treatment had also recorded highest dry matter production at 30 DAP during 2002-03 (0.21 t/ha) and 2003-04 (0.23 t/ha). Further, T4 (0.19 t/ha), T6 (0.19 t/ha) and T9 (0.19 t/ha) at 30 DAP; T3 (0.70 t/ha), T4 (0.69 t/ha), T5 (0.67 t/ha), T6 (0.67 t/ha) and T8 (0.72 t/ha) at 60 DAP; T3 (1.44 t/ha), T4 (1.45 t/ha), T6 (1.44 t/ha) and T8 (1.52 t/ha) at 90 DAP; T3 (4.13 t/ha), T4 (4.11 t/ha), T6 (4.09 t/ha), T8 (4.33 t/ha) and T9 (4.01 t/ha) at 120 DAP; T2 (7.04 t/ha), T3 (7.47 t/ha), T4 (7.42 t/ha), T6 (7.46 t/ha), T8 (7.56 t/ha), T9 (7.25 t/ha), T10 (7.04 t/ha), T11 (7.36 t/ha), T12 (7.34 t/ha) and T13 (7.00 t/ha), at 150 DAP; and T3 (9.84

Table 7 : Total drymatter production (tonnes per hectare) of cassava at different growth stages as influenced by integrated nutrient management under rainfed conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	0.17	0.19	0.18	0.46	0.52	0.49	1.15	1.30	1.23	3.42	3.97	3.69	5.30	6.00	5.65	6.57	7.39
T ₂ (RDF+FYM)	0.18	0.21	0.20	0.61	0.70	0.66	1.35	1.54	1.44	3.75	4.28	4.01	7.04	8.03	7.54	8.65	9.88	9.27
T ₃ (RDF+FYM+AZOS)	0.20	0.22	0.21	0.70	0.80	0.75	1.44	1.64	1.54	4.13	4.70	4.42	7.47	8.48	7.98	9.84	11.14	10.49
T ₄ (1/3 RDF+FYM+AZOS)	0.19	0.22	0.21	0.69	0.77	0.73	1.45	1.65	1.55	4.11	4.69	4.40	7.42	8.48	7.95	9.74	11.12	10.43
T ₅ (1/2 RDF+FYM+AZOS)	0.18	0.20	0.19	0.67	0.77	0.72	1.31	1.49	1.40	3.69	4.21	3.95	6.87	7.84	7.36	8.44	9.64	9.04
T ₆ (RDF+VC)	0.19	0.22	0.20	0.67	0.77	0.72	1.44	1.65	1.55	4.09	4.67	4.38	7.46	8.52	7.99	9.73	11.11	10.42
T ₇ (RDF+VC+AZOS)	0.21	0.23	0.22	0.74	0.85	0.80	1.56	1.78	1.67	4.39	5.01	4.70	7.57	8.64	8.11	9.93	11.34	10.63
T ₈ (1/3 RDF+VC+AZOS)	0.21	0.23	0.22	0.72	0.82	0.77	1.52	1.73	1.62	4.33	4.94	4.63	7.56	8.63	8.09	9.92	11.33	10.62
T ₉ (1/2 RDF+VC+AZOS)	0.19	0.22	0.20	0.66	0.75	0.71	1.41	1.61	1.51	4.01	4.58	4.29	7.25	8.27	7.76	9.52	10.87	10.20
T ₁₀ (RDF+GM)	0.17	0.20	0.18	0.55	0.62	0.59	1.22	1.40	1.31	3.27	4.20	3.73	7.04	8.03	7.54	8.63	9.88	9.26
T ₁₁ (RDF+GM+AZOS)	0.18	0.20	0.19	0.59	0.67	0.63	1.34	1.53	1.44	3.73	4.26	4.00	7.36	8.40	7.88	9.22	10.52	9.87
T ₁₂ (1/3 RDF+GM+AZOS)	0.18	0.20	0.19	0.57	0.65	0.61	1.33	1.52	1.43	3.71	4.24	3.97	7.34	8.38	7.86	9.20	10.50	9.85
T ₁₃ (1/2 RDF+GM+AZOS)	0.17	0.19	0.18	0.52	0.60	0.56	1.19	1.36	1.28	3.64	4.15	3.90	7.00	7.99	7.49	8.31	9.49	8.90
General Mean	0.18	0.21		0.63	0.72		1.36	1.55		3.87	4.45		7.13	8.13		9.05	10.32	
S.E.m	0.01	0.01		0.03	0.03		0.05	0.06		0.16	0.17		0.23	0.28		0.31	0.37	
C.D (0.05)	0.02	0.03		0.08	0.09		0.14	0.17		0.47	0.48		0.63	0.81		0.89	1.08	

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t/ha), T4 (9.74 t/ha), T6 (9.73 t/ha), T8 (9.92 t/ha), T9 (9.52 t/ha), T11 (9.22 t/ha) and T12 (9.20 t/ha) at 180 DAP during 2002-03; T2 (0.21 t/ha), T3 (0.22 t/ha), T4 (0.22 t/ha), T5 (0.20 t/ha), T6 (0.22 t/ha), T9 (0.22 t/ha), T10 (0.20 t/ha), T11 (0.20 t/ha) and T12 (0.20 t/ha) at 30 DAP; T3 (0.80 t/ha), T4 (0.77 t/ha), T5 (0.77 t/ha), T6 (0.77 t/ha) and T8 (0.82 t/ha) at 60 DAP; T3 (1.64 t/ha), T4 (1.65 t/ha), T6 (1.65 t/ha), T8 (1.73 t/ha) and T9 (1.61 t/ha) at 90 DAP; T3 (4.70 t/ha), T4 (4.69 t/ha), T6 (4.67 t/ha), T8 (4.94 t/ha) and T9 (4.58 t/ha) at 120 DAP; T2 (8.03 t/ha), T3 (8.48 t/ha), T4 (8.48 t/ha), T5 (7.84 t/ha), T6 (8.52 t/ha), T8 (8.63 t/ha), T9 (8.27 t/ha), T10 (8.03 t/ha), T11 (8.40 t/ha), T12 (8.38 t/ha) and T13 (7.99 t/ha) at 150 DAP; and T3 (11.14 t/ha), T4 (11.12 t/ha), T6 (11.11 t/ha), T8 (11.33 t/ha), T9 (10.87 t/ha), T11 (10.52 t/ha) and T12 (10.50 t/ha) at 180 DAP during 2003-04 had recorded total dry matter production on a par with T7 treatment. However, lowest dry matter production was recorded by T1 treatment at 30, 60, 90, 150 and 180 DAP during 2002-03 (0.17 t/ha, 0.46 t/ha, 1.15 t/ha, 5.30 t/ha and 6.57 t/ha, respectively); and 2003-04 (0.19 t/ha, 0.52 t/ha, 1.15 t/ha, 6.0 t/ha and 7.39 t/ha, respectively). The treatment had also recorded lowest dry matter at 120 DAP during 2003-04 (3.97 t/ha). In addition, T10 (0.17 t/ha) and T13 (0.17 t/ha) at 30 DAP; and T10 (3.27 t/ha) at 120 DAP during 2002-03; and T13 (0.19 t/ha) at 30 DAP during 2003-04 had also recorded lowest dry matter production.

4.1.8 Dry matter partitioning at harvest

The results are presented in Table 8 and Figure 3.

4.1.8.1 Stem dry matter

The stem dry matter was in general observed to be higher during 2003-04 (2.88 t/ha), compared to 2002-03 (2.44 t/ha). Significant influence of the INM

Table 8 : Stem, leaf, tuber and total drymatter production (tonnes per hectare) of cassava at harvest (210 DAP) as influenced by integrated nutrient management under rainfed conditions

Treatments	Stem drymatter			Leaf drymatter			Tuber drymatter			Total drymatter		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	2.07	2.48	2.28	1.52	1.74	1.63	2.99	3.49	3.24	6.58	7.71	7.15
T ₂ (RDF+FYM)	2.45	2.85	2.65	1.87	2.15	2.01	4.57	5.22	4.90	8.89	10.22	9.56
T ₃ (RDF+FYM+AZOS)	2.62	3.06	2.84	1.95	2.33	2.14	6.02	6.86	6.44	10.59	12.25	11.42
T ₄ (1/3 RDF+FYM+AZOS)	2.49	2.98	2.74	1.90	2.18	2.04	5.98	6.82	6.40	10.37	11.98	11.18
T ₅ (1/2 RDF+FYM+AZOS)	2.37	2.72	2.55	1.79	2.08	1.90	4.51	5.15	4.83	8.67	9.88	9.28
T ₆ (RDF+VC)	2.66	3.06	2.86	2.04	2.35	2.20	6.00	6.85	6.43	10.70	12.26	11.48
T ₇ (RDF+VC+AZOS)	2.80	3.32	3.06	2.13	2.48	2.31	7.04	8.03	7.54	11.97	13.84	12.91
T ₈ (1/3 RDF+VC+AZOS)	2.63	3.11	2.87	2.09	2.38	2.24	6.92	7.90	7.41	11.64	13.39	12.52
T ₉ (1/2 RDF+VC+AZOS)	2.80	3.03	2.92	1.96	2.18	2.06	5.96	6.80	6.38	10.72	11.99	11.36
T ₁₀ (RDF+GM)	2.18	2.62	2.40	1.76	1.98	1.84	4.05	4.62	4.34	7.99	9.16	8.58
T ₁₁ (RDF+GM+AZOS)	2.32	2.97	2.65	1.90	2.18	2.03	4.74	5.41	5.08	8.96	10.54	9.75
T ₁₂ (1/3 RDF+GM+AZOS)	2.19	2.69	2.44	1.79	1.98	1.88	4.71	5.37	5.04	8.69	10.02	9.36
T ₁₃ (1/2 RDF+GM+AZOS)	2.11	2.51	2.31	1.64	1.98	1.77	4.00	4.57	4.29	7.75	8.97	8.36
General Mean	2.44	2.88		1.87	2.13		5.19	5.93		9.50	10.94	
S.E.m	0.10	0.11		0.08	0.11		0.37	0.40		0.34	0.37	
C.D (0.05)	0.29	0.32		0.23	0.28		1.08	1.18		1.00	1.08	

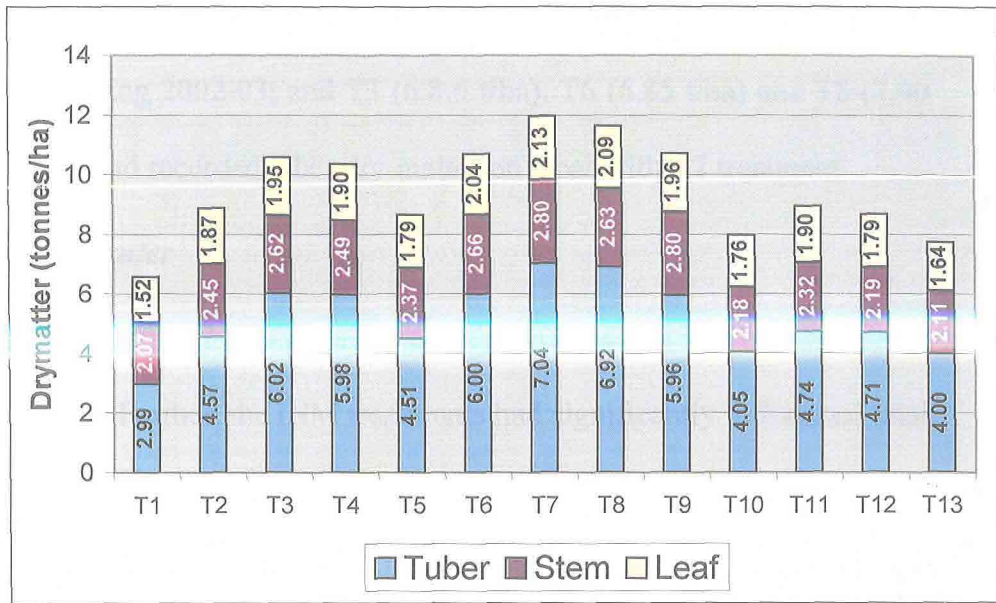
treatments studied in the present investigation was also observed during both the years of investigation. T7 treatment had recorded highest stem dry matter (2.80 t/ha and 3.32 t/ha, respectively), while T1 treatment had recorded lowest stem dry matter (2.07 t/ha and 2.48 t/ha, respectively), during 2002-03 and 2003-04. The treatments, T3 (2.62 t/ha), T6 (2.66 t/ha) and T8 (2.63 t/ha) during 2002-03; and T3 (3.06 t/ha), T6 (3.06 t/ha), T8 (3.11 t/ha) and T9 (3.03 t/ha) during 2003-04 had recorded stem dry matter on a par with T7 treatment. Further, T9 treatment during 2002-03 had recorded highest stem dry matter (2.80 t/ha).

4.1.8.2 Leaf dry matter

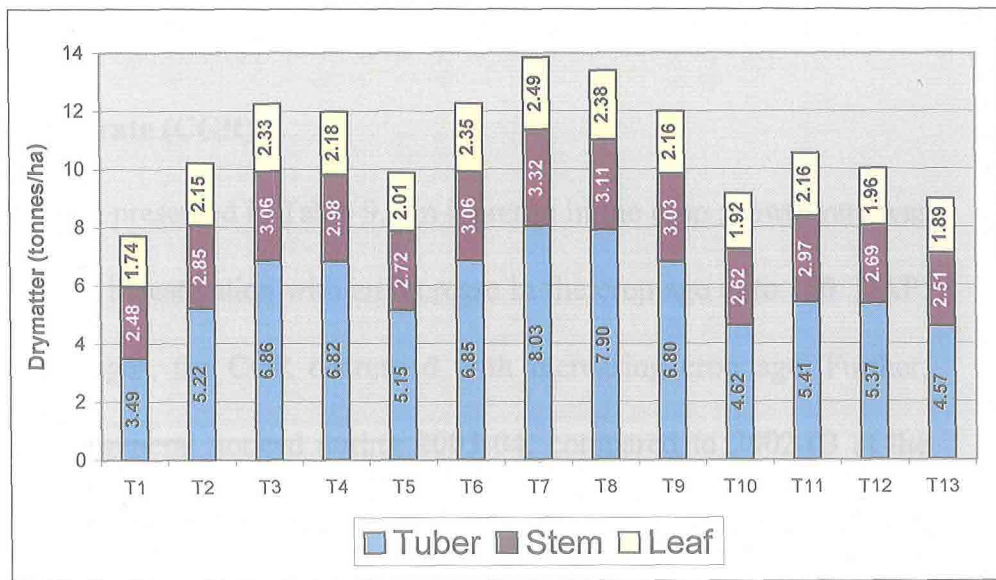
Leaf dry matter was noticed to be higher during 2003-04 (2.13 t/ha), compared to 2002-03 (1.87 t/ha). The different INM treatments studied in the present investigation exerted significant influence on the leaf dry matter. The T7 treatment had recorded highest leaf dry matter (2.13 t/ha and 2.49 t/ha, respectively), while T1 treatment had recorded lowest leaf dry matter (1.52 t/ha and 1.74 t/ha, respectively), during 2002-03 and 2003-04. The treatments, T3 (1.95 t/ha), T4 (1.90 t/ha), T6 (2.04 t/ha), T8 (2.09 t/ha), T9 (1.96 t/ha) and T11 (1.90 t/ha) during 2002-03; and T2 (2.15 t/ha), T3 (2.33 t/ha), T4 (2.18 t/ha), T6 (2.35 t/ha), T8 (2.38 t/ha), T9 (2.16 t/ha) and T11 (2.16 t/ha) during 2003-04 had also recorded leaf dry matter on a par with T7 treatment.

4.1.8.3 Tuber dry matter

Greater tuber dry matter was noticed during 2003-04 (5.93 t/ha), compared to 2002-03 (5.19 t/ha). Significant influence of INM treatments was also recorded by the character during both the years of investigation. T7 treatment had recorded



2002-03



2003-04

Fig.3. Drymatter partitioning in cassava at harvest as influenced by integrated nutrient management under rainfed conditions

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highest tuber dry matter (7.04 t/ha and 8.03 t/ha, respectively), while T1 had recorded lowest tuber dry matter (2.99 t/ha and 3.49 t/ha, respectively), during 2002-03 and 2003-04. Further, T3 (6.02 t/ha), T4 (5.98 t/ha), T6 (6.00 t/ha), T8 (6.92 t/ha) and T9 (5.96 t/ha) during 2002-03; and T3 (6.8.6 t/ha), T6 (6.85 t/ha) and T8 (7.90 t/ha) during 2003-04 had recorded tuber dry matter on a par with T7 treatment.

4.1.8.4 Total dry matter

Higher total dry matter was recorded during 2003-04 (10.94 t/ha), compared to 2002-03 (9.50 t/ha). Further, the INM treatments had significantly influenced total dry matter production during both 2002-03 and 2003-04. Among the treatments, T7 had recorded highest total dry matter (11.97 t/ha and 13.84 t/ha, respectively), followed by T8 treatment (11.64 t/ha and 13.39 t/ha, respectively), while T1 had recorded lowest total dry matter (6.58 t/ha and 7.71 t/ha, respectively), during 2002-03 and 2003-04.

4.1.9 Crop growth rate (CGR)

The results are presented in Table 9. An increase in the crop growth rate was noticed in the present investigation with an increase in the crop age upto 150 DAP. However, at later stages, the CGR decreased with increasing crop age. Further, greater CGR was in general noticed during 2003-04, compared to 2002-03 at the different growth stages studied. The influence of different INM treatments studied in the present investigation was also found to be non-significant at 30-60 DAP, 60-90 DAP, 150-180 DAP and 180-210 DAP. However, significant influence of the treatments was recorded at 90-120 DAP and 120-150 DAP.

Table 9 : Crop growth rate ($\text{g m}^{-2} \text{day}^{-1}$) at different growth stages in cassava as influenced by integrated nutrient management under rainfed conditions

Treatments	30-60 DAP			60-90 DAP			90-120 DAP			120-150 DAP			150-180 DAP			180-210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	0.98	1.13	1.05	2.31	2.59	2.45	7.54	8.91	8.22	6.30	6.77	6.53	4.22	4.63	4.42	2.99	4.12
T ₂ (RDF+FYM)	1.44	1.64	1.54	2.44	2.79	2.62	8.00	9.13	8.56	10.97	12.53	11.75	5.39	6.16	5.78	1.96	2.23	2.09
T ₃ (RDF+FYM+AZOS)	1.68	1.92	1.80	2.45	2.79	2.62	9.00	10.20	9.60	11.13	12.62	11.87	7.90	8.87	8.39	2.52	3.19	2.86
T ₄ (1/3 RDF+FYM+AZOS)	1.66	1.84	1.75	2.53	2.92	2.73	8.86	10.15	9.51	11.05	12.61	11.83	7.72	8.81	8.26	2.80	3.19	3.00
T ₅ (1/2 RDF+FYM+AZOS)	1.65	1.88	1.77	2.12	2.42	2.27	7.93	9.05	8.49	10.61	12.11	11.36	5.24	5.98	5.61	2.51	2.86	2.69
T ₆ (RDF+VC)	1.61	1.84	1.73	2.57	2.93	2.75	8.83	10.09	9.46	11.23	12.82	12.03	7.56	8.63	8.10	2.89	3.30	3.09
T ₇ (RDF+VC+AZOS)	1.80	2.05	1.92	2.72	3.11	2.91	9.43	10.77	10.10	10.61	12.11	11.36	7.86	8.98	8.42	5.11	5.84	5.47
T ₈ (1/3 RDF+VC+AZOS)	1.70	1.94	1.82	2.67	3.05	2.86	9.37	10.70	10.04	10.77	12.29	11.53	7.88	9.00	8.44	4.80	5.48	5.14
T ₉ (1/2 RDF+VC+AZOS)	1.57	1.79	1.68	2.51	2.87	2.69	8.65	9.88	9.27	10.80	12.33	11.57	7.58	8.66	8.12	3.46	3.95	3.70
T ₁₀ (RDF+GM)	1.25	1.43	1.34	2.26	2.58	2.42	6.80	9.33	8.07	12.57	12.79	12.68	5.32	6.15	5.73	0.23	0.19	0.21
T ₁₁ (RDF+GM+AZOS)	1.36	1.55	1.46	2.52	2.88	2.70	7.97	9.10	8.53	12.08	13.79	12.94	6.20	7.08	6.64	0.65	0.74	0.69
T ₁₂ (1/3 RDF+GM+AZOS)	1.32	1.51	1.41	2.53	2.89	2.71	7.93	9.05	8.49	12.10	13.81	12.96	6.20	7.08	6.64	0.63	0.72	0.68
T ₁₃ (1/2 RDF+GM+AZOS)	1.19	1.36	1.27	2.24	2.55	2.39	8.15	9.30	8.73	11.19	12.77	11.98	4.39	5.01	4.70	1.14	1.30	1.22
General Mean	1.48	1.68		2.45	2.80		8.34	9.67		10.88	12.26		6.42	7.31		2.44	2.85	
S.E.m	0.08	0.10		0.17	0.19		0.47	0.43		0.81	1.02		1.21	1.46		1.38	1.55	
C.D (0.05)	NS	NS		NS	NS		1.37	1.25		2.37	2.97		NS	NS		NS	NS	

Among the treatments, T7 had recorded highest CGR during 2002-03 (9.43 g m⁻²day⁻¹) and 2003-04 (10.77 g m⁻²day⁻¹) at 90-120 DAP. The treatments, T3 (9.0 g m⁻²day⁻¹), T4 (8.86 g m⁻²day⁻¹), T6 (8.83 g m⁻²day⁻¹), T8 (9.37 g m⁻²day⁻¹), T9 (8.65 g m⁻²day⁻¹) and T13 (8.15 g m⁻²day⁻¹) during 2002-03; and T3 (10.20 g m⁻²day⁻¹), T4 (10.15 g m⁻²day⁻¹), T6 (10.09 g m⁻²day⁻¹), T8 (10.70 g m⁻²day⁻¹) and T9 (9.88 g m⁻²day⁻¹) during 2003-04 had also recorded CGR on a par with T7 treatment. However, lowest CGR was recorded by T10 (6.80 g m⁻²day⁻¹) treatment during 2002-03; and T1 (8.91 g m⁻²day⁻¹) treatment during 2003-04 at 90-120 DAP.

At 120-150 DAP, highest CGR was observed by T10 treatment (12.57 g m⁻²day⁻¹) during 2002-03; and T12 treatment (13.81 g m⁻²day⁻¹) during 2003-04. Further, the treatments, T2 (10.97 g m⁻²day⁻¹), T3 (11.13 g m⁻²day⁻¹), T4 (11.05 g m⁻²day⁻¹), T5 (10.61 g m⁻²day⁻¹), T6 (11.23 g m⁻²day⁻¹), T7 (10.61 g m⁻²day⁻¹), T8 (10.77 g m⁻²day⁻¹), T9 (10.80 g m⁻²day⁻¹), T11 (12.08 g m⁻²day⁻¹), T12 (12.10 g m⁻²day⁻¹) and T13 (11.19 g m⁻²day⁻¹) during 2002-03; and T2 (12.53 g m⁻²day⁻¹), T3 (12.62 g m⁻²day⁻¹), T4 (12.61 g m⁻²day⁻¹), T5 (12.11 g m⁻²day⁻¹), T6 (12.82 g m⁻²day⁻¹), T7 (12.11 g m⁻²day⁻¹), T8 (12.29 g m⁻²day⁻¹), T9 (12.33 g m⁻²day⁻¹), T10 (12.79 g m⁻²day⁻¹), T11 (13.79 g m⁻²day⁻¹) and T13 (12.77 g m⁻²day⁻¹) during 2003-04 had recorded CGR on a par with the best treatment.

4.1.10 Net assimilation rate (NAR)

The results are presented in Table 10. The influence of different INM treatments studied in the present investigation on NAR, at 30-60 DAP, 60-90 DAP,

Table 10 : Net assimilation rate ($\text{g m}^{-2} \text{ day}^{-1}$) at different growth stages in cassava as influenced by integrated nutrient management under rainfed conditions

Treatments	30-60 DAP			60-90 DAP			90-120 DAP			120-150 DAP			150-180 DAP			180-210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	0.516	0.790	0.653	1.800	2.120	1.960	4.820	5.010	4.915	5.610	6.160	5.885	2.740	3.120	2.930	0.560	1.120	0.840
T ₂ (RDF+FYM)	0.764	1.330	1.047	1.560	1.840	1.700	4.740	5.260	5.000	7.350	7.850	7.600	4.630	4.770	4.700	0.621	1.850	1.236
T ₃ (RDF+FYM+AZOS)	1.480	1.870	1.675	2.390	2.870	2.630	6.480	7.160	6.820	7.420	8.840	8.130	4.890	6.560	5.725	1.753	1.887	1.820
T ₄ (1/3 RDF+FYM+AZOS)	0.629	1.590	1.110	1.870	2.150	2.010	4.850	5.130	4.990	7.350	7.800	7.575	4.070	4.330	4.200	0.851	1.090	0.971
T ₅ (1/2 RDF+FYM+AZOS)	0.875	1.930	1.403	1.280	1.740	1.510	4.360	5.770	5.065	7.470	7.970	7.720	4.400	4.780	4.590	0.890	1.390	1.140
T ₆ (RDF+VC)	1.215	1.840	1.528	2.580	2.760	2.670	6.160	7.240	6.700	7.960	8.890	8.425	4.850	6.770	5.810	2.200	2.980	2.590
T ₇ (RDF+VC+AZOS)	1.830	1.090	1.460	2.800	3.100	2.950	6.780	7.540	7.160	8.370	9.510	8.940	5.100	6.900	6.000	2.390	3.440	2.915
T ₈ (1/3 RDF+VC+AZOS)	1.270	1.790	1.530	2.250	2.610	2.430	6.500	7.190	6.845	7.220	8.980	8.100	4.670	6.720	5.695	2.140	2.740	2.440
T ₉ (1/2 RDF+VC+AZOS)	0.697	1.760	1.229	2.180	2.580	2.380	4.720	5.720	5.220	7.120	8.060	7.590	4.580	6.290	5.435	0.520	1.260	0.890
T ₁₀ (RDF+GM)	0.853	1.570	1.212	1.730	2.020	1.875	4.020	5.160	4.590	7.410	8.070	7.740	4.130	6.030	5.080	0.786	1.500	1.143
T ₁₁ (RDF+GM+AZOS)	1.060	1.630	1.345	1.560	1.960	1.760	4.440	5.930	5.185	7.120	8.260	7.690	4.280	5.820	5.050	1.881	2.390	2.136
T ₁₂ (1/3 RDF+GM+AZOS)	0.913	1.730	1.322	1.480	1.930	1.705	4.610	5.030	4.820	6.890	7.640	7.265	4.190	5.160	4.675	1.739	2.135	1.937
T ₁₃ (1/2 RDF+GM+AZOS)	0.614	0.970	0.792	1.900	1.810	1.855	5.120	5.540	5.330	6.460	7.790	7.125	3.800	4.790	4.295	0.918	1.500	1.209
General Mean	0.978	1.530		1.952	2.268		5.200	5.975		7.212	8.140		4.333	5.542		1.327	1.945	
S.Em	0.217	0.235		0.162	0.163		0.217	0.158		0.292	0.235		0.404	0.417		0.492	0.527	
C.D (0.05)	NS	NS		NS	NS		0.640	0.461		0.852	0.685		NS	NS		NS	NS	

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150-180 DAP and 180-210 DAP was non-significant, while the effect at 90-120 DAP and 120-150 DAP was significant.

At 90-120 DAP, T7 treatment had recorded highest NAR during 2002-03 ($6.78 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($7.54 \text{ g m}^{-2}\text{day}^{-1}$). The treatments T3 ($6.48 \text{ g m}^{-2}\text{day}^{-1}$ and $7.16 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($6.16 \text{ g m}^{-2}\text{day}^{-1}$ and $7.24 \text{ g m}^{-2}\text{day}^{-1}$) and T8 ($6.50 \text{ g m}^{-2}\text{day}^{-1}$ and $7.19 \text{ g m}^{-2}\text{day}^{-1}$) had also recorded NAR on a par with T7 treatment during 2002-03 and 2003-04, respectively. Further, lowest NAR was recorded by T10 ($4.02 \text{ g m}^{-2}\text{day}^{-1}$) during 2002-03 and T1 ($5.01 \text{ g m}^{-2}\text{day}^{-1}$) during 2003-04.

At 120-150 DAP also, T7 had recorded highest NAR during both 2002-03 ($8.37 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($9.51 \text{ g m}^{-2}\text{day}^{-1}$). The treatment, T6 ($7.96 \text{ g m}^{-2}\text{day}^{-1}$) during 2002-03; and T3 ($8.84 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($8.89 \text{ g m}^{-2}\text{day}^{-1}$) and T8 ($8.89 \text{ g m}^{-2}\text{day}^{-1}$) during 2003-04 had recorded NAR on a par with T7 treatment. Further, T1 had recorded lowest NAR during both 2002-03 ($5.61 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($6.16 \text{ g m}^{-2}\text{day}^{-1}$).

4.1.11 Shoot/root ratio

The results are presented in Table 11. A significant influence of the treatments studied was observed on shoot/root ratio during 2002-03 and 2003-04. T1 treatment had recorded highest shoot/root ratio during 2002-03 (1.49) and 2003-04 (1.38), while lowest shoot/root ratio was recorded by T7 during both 2002-03 (0.63) and 2003-04 (0.60). Further, the treatments T3 (0.76 and 0.72), T4 (0.77 and 0.74), T6 (0.77 and 0.75), T8 (0.64 and 0.62) and T9 (0.77 and 0.71) had also recorded shoot/root ratio on a par with T7 treatment during 2002-03 and 2003-04, respectively.

Table 11: Shoot /root ratio in cassava as influenced by integrated nutrient management under rainfed conditions

Treatments	Shoot/root ratio		
	02-03	03-04	Mean
T ₁ (RDF)	1.49	1.38	1.48
T ₂ (RDF+FYM)	1.02	0.92	1.02
T ₃ (RDF+FYM+AZOS)	0.76	0.72	0.76
T ₄ (² / ₃ RDF+FYM+AZOS)	0.77	0.74	0.77
T ₅ (¹ / ₂ RDF+FYM+AZOS)	1.04	1.01	1.04
T ₆ (RDF+VC)	0.77	0.75	0.77
T ₇ (RDF+VC+AZOS)	0.63	0.60	0.63
T ₈ (² / ₃ RDF+VC+AZOS)	0.64	0.62	0.64
T ₉ (¹ / ₂ RDF+VC+AZOS)	0.77	0.71	0.77
T ₁₀ (RDF+GM)	1.15	1.11	1.15
T ₁₁ (RDF+GM+AZOS)	0.99	0.95	0.98
T ₁₂ (² / ₃ RDF+GM+AZOS)	1.00	0.97	1.00
T ₁₃ (¹ / ₂ RDF+GM+AZOS)	1.16	1.03	1.16
General Mean	0.94	0.89	
S.Em	0.06	0.09	
C.D (0.05)	0.18	0.26	

4.1.12 Yield and yield attributes

The experimental results obtained with regards to the effect of different INM treatments on number of tubers per plant, tuber length, tuber diameter, Fresh to dry weight of tubers, tuber weight per plant and yield per hectare are presented in Table 12.

4.1.12.1 Number of tubers per plant

The number of tubers per plant was in general observed to be higher during 2003-04 (6.97), compared to 2002-03 (6.26). A significant influence of the different treatments studied in the present investigation was also observed for number of tubers per plant during 2002-03 and 2003-04. Among the treatments, T7 had recorded highest number of tubers per plant during both 2002-03 (6.74) and 2003-04 (7.31). The treatments, T2 (6.27), T3 (6.54), T4 (6.57), T6 (6.68), T8 (6.66) and T9 (6.71) during 2002-03, and T2 (6.82), T3 (7.27), T4 (7.16), T5 (7.13), T6 (7.27), T8 (7.10), T9 (7.07), T11 (6.89) and T12 (6.88) during 2003-04 had also recorded number of tubers per plant on a par with T7 treatment.

4.1.12.2 Tuber length

Tuber length was observed to range from 21.21 (T1) to 25.04 (T7) cm with a mean of 23.43 cm during 2002-03; and 23.20 (T1) to 28.20 (T3) cm with a mean of 25.06 cm during 2003-04. However, the effect of different INM treatments studied in the present investigation was non-significant on tuber length during both 2002-03 and 2003-04.

Table 12 : Yield and yield attributes in cassava as influenced by integrated nutrient management under rainfed conditions

Treatments	Number of tubers per plant				Tuber length (cm)				Tuber diameter (cm)				Fresh to dry weight of tubers (%)				Tuber weight per plant (kg)				Yield per hectare (tonnes)			
	02-03		03-04		02-03		03-04		02-03		03-04		02-03		03-04		02-03		03-04		02-03		03-04	
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	
T ₁ (RDF)	5.57	6.66	6.11	21.21	23.20	22.21	6.72	8.50	7.61	29.80	30.10	29.95	1.05	1.45	1.25	12.98	16.34	14.66						
T ₂ (RDF+FYM)	6.27	6.82	6.54	23.51	26.00	24.75	8.31	8.91	8.61	32.18	31.87	32.03	1.35	1.76	1.56	14.99	22.25	18.62						
T ₃ (RDF+FYM+AZOS)	6.54	7.27	6.91	23.71	28.20	25.96	8.54	9.88	9.21	34.13	34.26	34.20	1.68	2.10	1.89	19.21	24.83	22.02						
T ₄ (1/3 RDF+FYM+AZOS)	6.57	7.16	6.86	23.60	27.00	25.30	8.26	9.52	8.89	32.86	33.92	33.39	1.54	1.88	1.71	18.10	23.84	20.97						
T ₅ (1/2 RDF+FYM+AZOS)	6.03	7.13	6.58	23.72	26.00	24.86	8.80	9.48	9.14	31.14	32.64	31.89	1.34	1.70	1.52	14.36	21.04	17.70						
T ₆ (RDF+VC)	6.68	7.27	6.97	23.81	23.67	23.74	8.52	9.44	8.98	33.58	34.18	33.88	1.62	1.94	1.78	18.89	24.04	21.47						
T ₇ (RDF+VC+AZOS)	6.74	7.31	6.88	25.04	26.70	25.87	8.72	10.38	9.55	34.69	35.16	34.93	1.96	2.35	2.16	21.21	26.58	23.90						
T ₈ (1/3 RDF+VC+AZOS)	6.66	7.10	6.88	24.95	24.90	24.93	8.24	9.46	8.85	34.00	34.58	34.29	1.82	2.32	2.07	20.80	25.89	23.35						
T ₉ (1/2 RDF+VC+AZOS)	6.71	7.07	6.89	24.24	24.73	24.49	8.24	8.56	8.40	32.67	32.86	32.77	1.51	1.86	1.69	17.68	23.05	20.37						
T ₁₀ (RDF+GM)	5.61	6.71	6.16	22.16	24.20	23.18	7.41	8.80	8.11	30.68	32.08	31.38	1.31	1.59	1.45	13.86	20.57	17.22						
T ₁₁ (RDF+GM+AZOS)	6.04	6.89	6.47	23.88	24.09	23.98	7.70	9.42	8.56	32.53	33.16	32.85	1.45	1.81	1.63	16.02	22.93	19.48						
T ₁₂ (1/3 RDF+GM+AZOS)	5.98	6.88	6.43	22.93	23.43	23.18	7.51	9.24	8.38	31.26	32.00	31.63	1.40	1.77	1.59	15.00	22.74	18.87						
T ₁₃ (1/2 RDF+GM+AZOS)	5.96	6.35	6.16	21.84	23.67	22.76	6.96	8.94	7.95	30.42	31.24	30.83	1.18	1.54	1.36	13.48	19.13	16.31						
General Mean	6.26	6.97	6.61	23.43	25.06	24.24	7.96	9.27	8.56	32.00	32.93	32.46	1.48	1.85	1.66	16.66	22.56	20.51						
S.E.m	0.20	0.17		1.30	1.13		0.52	0.43		1.40	1.03		0.15	0.13		1.23	0.82							
C.D (0.05)	0.59	0.50		NS	NS		1.52	1.25		NS	NS		0.43	0.39		3.60	2.40							

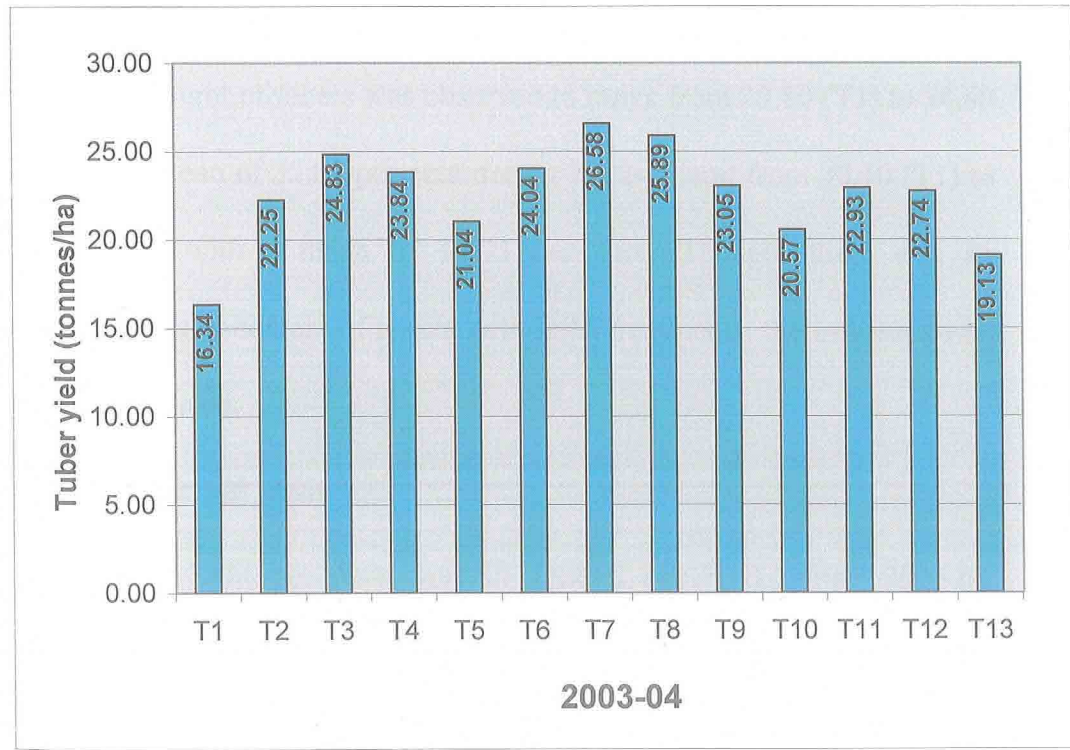
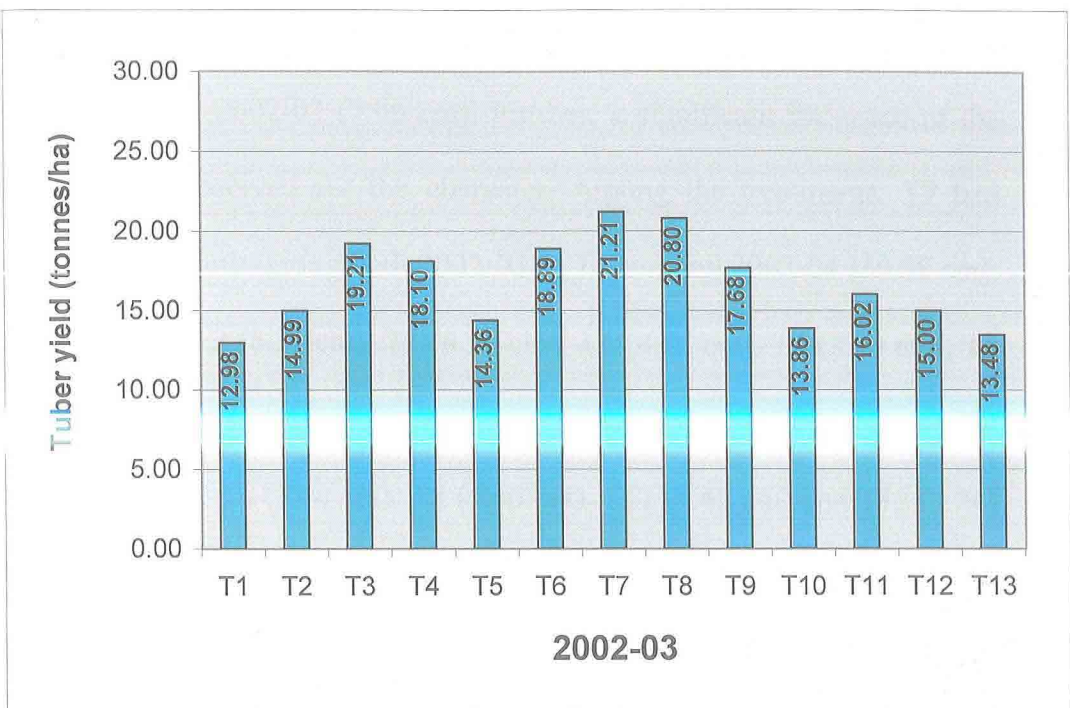


Fig. 4. Tuber yield (tonnes/ha) of cassava as influenced by integrated nutrient management under rainfed conditions

4.1.12.3 Tuber diameter

Tuber diameter was in general observed to be higher during 2003-04 (9.27 cm), compared to 2002-03 (7.96 cm). Further, a significant influence of the INM treatments was observed for the character. Among the treatments, T7 had recorded highest tuber girth during both 2002-03 (8.72 cm) and 2003-04 (10.38 cm). Further, the treatments T2 (8.31 cm), T3 (8.54 cm), T4 (8.26 cm), T5 (8.80 cm), T6 (8.52 cm), T8 (8.24 cm) and T9 (8.24 cm) during 2002-03; and T3 (9.88 cm), T4 (9.52 cm), T5 (9.48 cm), T6 (9.44 cm), T8 (9.46 cm), T11 (9.42 cm) and T12 (9.24) during 2003-04 had recorded tuber diameter on a par with T7 treatment. T1 treatment had recorded lowest tuber girth during both 2002-03 (6.72 cm) and 2003-04 (8.50 cm).

4.1.12.4 Fresh to dry weight of tuber

Fresh to dry weight of tubers was observed to range from 29.80 (T1) to 34.69 per cent (T7) with a mean of 32.00 per cent during 2002-03 and from 30.10 (T1) to 35.16 per cent (T7) with a mean of 32.93 per cent. Though, there was an improvement in dry mater content of tubers with INM treatments, the influence was found to be non-significant.

4.1.12.5 Tuber weight per plant

Higher tuber weight per plant was in general observed during 2003-04 (1.85 kg), compared to 2002-03 (1.48 kg). Further, a significant effect of the different INM treatments studied in the present investigation was observed for the character. Among the treatments, T7 had recorded highest tuber weight per plant during both 2002-03 (1.96 kg) and 2003-04 (2.35 kg). Further, the treatments T3

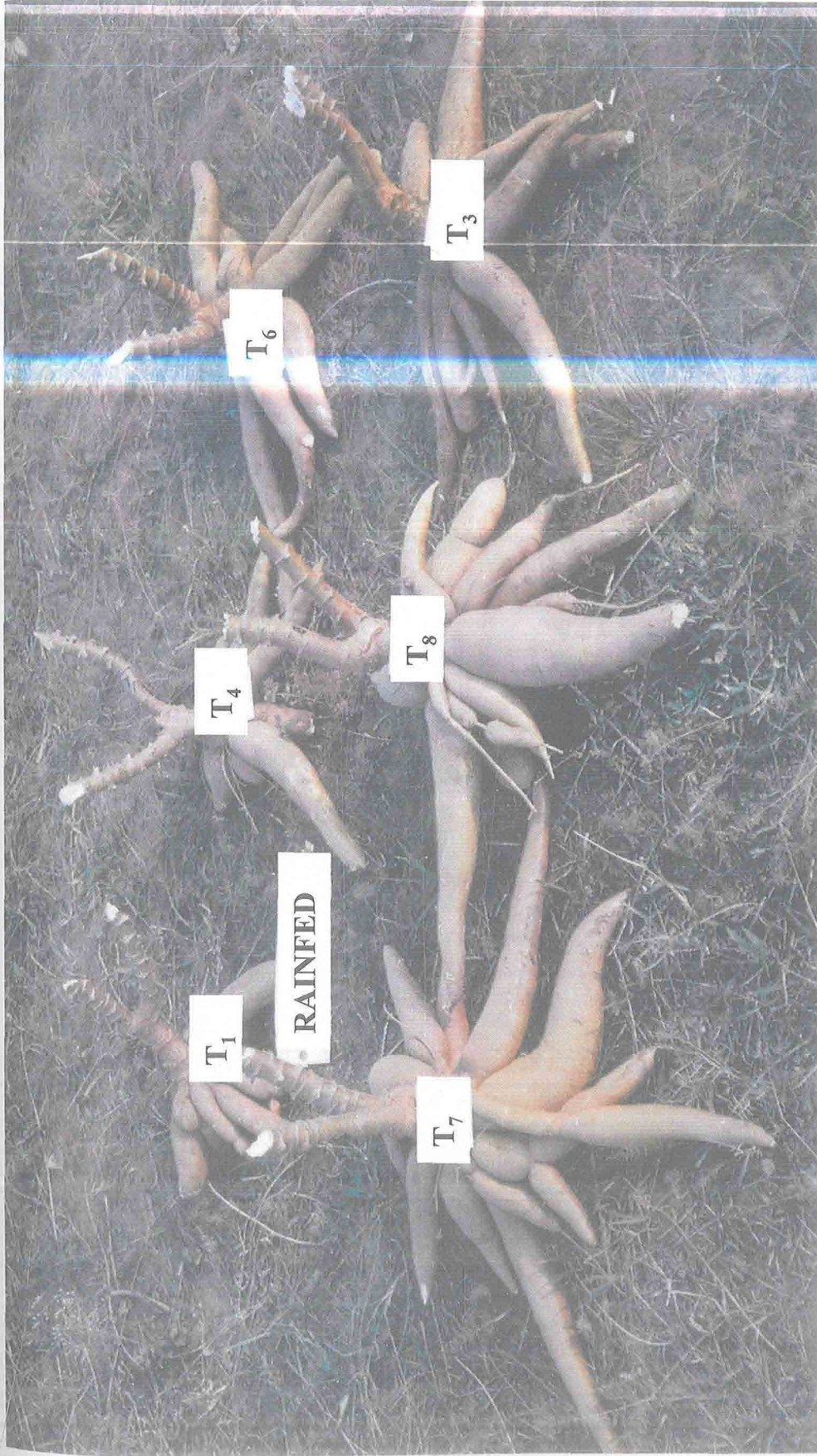


Plate 2 : Cassava tuber yield per plant in the superior integrated nutrient management treatments and application of inorganics alone (T1) during 2002-03

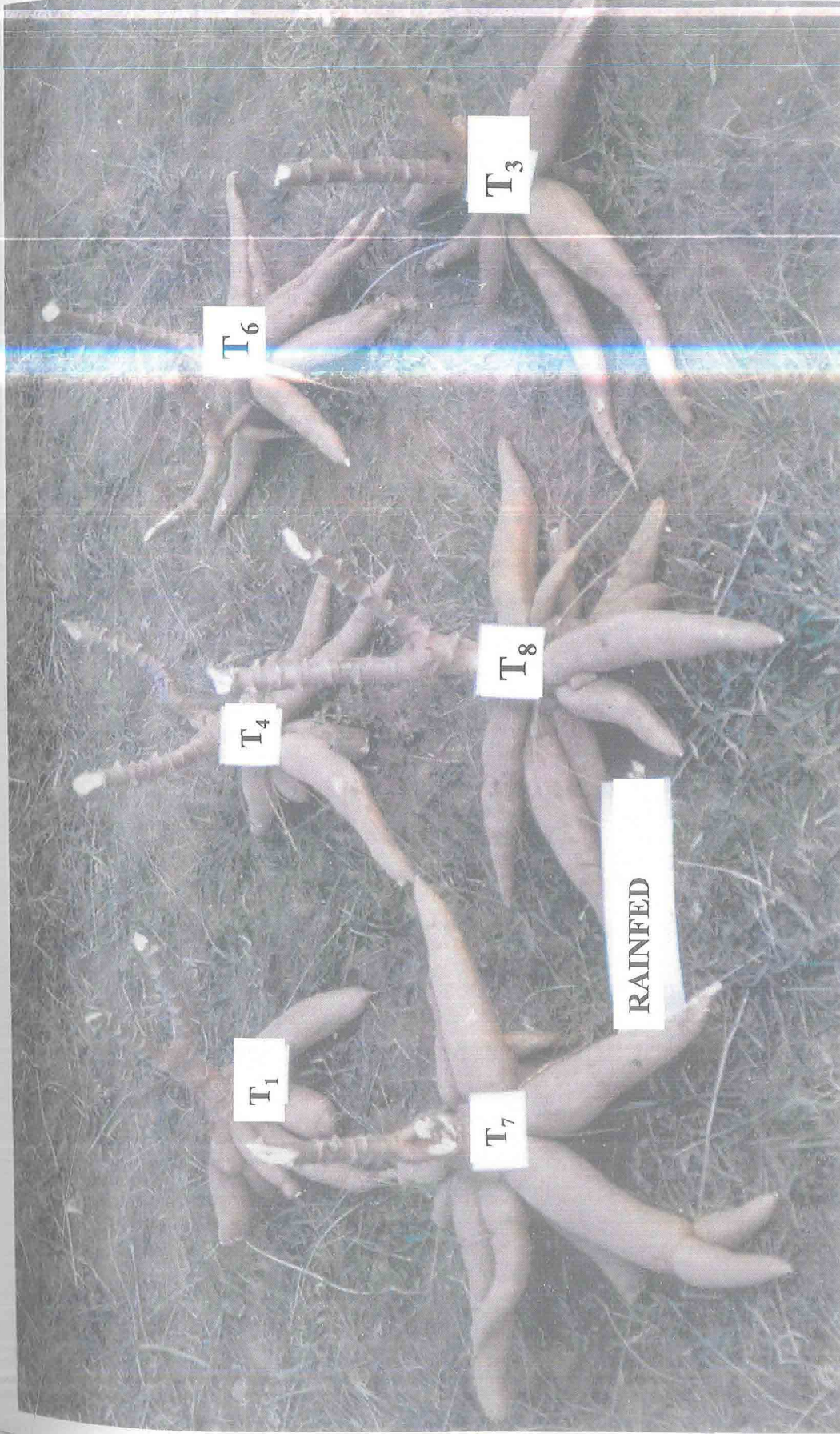


Plate 3: Cassava tuber yield per plant in the superior integrated nutrient management treatments and application of inorganics alone (T1) during 2003-04

(1.68 kg), T4 (1.54 kg), T6 (1.62 kg) and T8 (1.82 kg) during 2002-03 (Plate 2); and T3 (2.10 kg) and T8 (2.32 kg) during 2003-04 (Plate 3) had also recorded tuber weight per plant on a par with T7 treatment. Lowest tuber weight per plant was recorded by T1 treatment during both 2002-03 (1.05 kg) and 2003-04 (1.45 kg).

4.1.13 Yield per hectare

The tuber yield was in general noticed to be higher during 2003-04 (22.56 t), compared to 2002-03 (16.66 t). Further, a significant influence of the different INM treatments studied in the present investigation was recorded for this character. Among the treatments, T7 had recorded highest tuber yield per hectare during both 2002-03 (21.21 t) and 2003-04 (26.58 t). The treatments, T3 (19.21 t), T4 (18.10 t), T6 (18.89 t), T8 (20.80 t) and T10 (17.68 t) during 2002-03; and T3 (24.83 t) and T8 (25.89 t) during 2003-04 had recorded tuber yield per hectare on a par with T7 treatment. However, T1 treatment had recorded lowest yield per hectare during both 2002-03 (12.98 t) and 2003-04 (16.34 t) (Table 12 and Fig.4).

4.1.14 Quality attributes

The results pertaining to influence of the different INM treatments on quality attributes of the tuber namely, starch content, hydrocyanin content, crude fibre content and cooking time are presented in Table 13.

4.1.14.1 Starch content

The starch content of cassava was in general noticed to be higher during 2003-04, compared to 2002-03. Further, the starch content under different INM treatments was observed to range from 24.53 per cent (T1) to 29.16 per cent (T7) with an average of 26.88 per cent during 2002-03; and from 23.66 per cent (T1) to

Table 13 : Quality attributes in cassava as influenced by integrated nutrient management under rainfed conditions

Treatments	Starch content (%)			Hydrocyanin content ($\mu\text{g/g}$)			Crude fibre content (%)			Cooking time (minutes)		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	24.53	23.66	24.10	47.29	46.36	46.83	1.95	1.83	1.89	27.33	28.33	27.83
T ₂ (RDF+FYM)	27.51	27.94	27.73	49.36	49.88	49.62	1.94	1.84	1.89	27.33	27.33	27.33
T ₃ (RDF+FYM+AZOS)	28.55	30.07	29.31	49.10	49.46	49.28	1.87	1.81	1.84	29.67	29.00	29.34
T ₄ ($1/3$ RDF+FYM+AZOS)	28.98	29.28	29.13	48.46	49.28	48.87	1.98	1.73	1.86	28.00	28.67	28.34
T ₅ ($1/2$ RDF+FYM+AZOS)	25.76	26.73	26.25	48.67	48.55	48.61	1.91	1.62	1.77	25.00	28.67	26.84
T ₆ (RDF+VC)	26.69	28.10	27.40	49.44	49.49	49.47	1.73	1.86	1.80	30.33	28.00	29.17
T ₇ (RDF+VC+AZOS)	29.16	30.29	29.73	49.84	49.17	49.51	1.74	1.88	1.81	30.67	29.33	30.00
T ₈ ($1/3$ RDF+VC+AZOS)	28.96	28.97	28.97	49.22	48.46	48.84	1.82	1.87	1.85	28.00	28.33	28.17
T ₉ ($1/2$ RDF+VC+AZOS)	26.54	26.00	26.27	48.45	47.74	48.10	1.95	1.91	1.93	27.33	28.00	27.67
T ₁₀ (RDF+GM)	26.18	28.46	27.32	48.46	47.73	48.10	2.03	1.85	1.94	26.67	29.67	28.17
T ₁₁ (RDF+GM+AZOS)	26.25	27.82	27.04	48.59	48.24	48.42	1.83	1.87	1.85	27.67	28.00	27.84
T ₁₂ ($1/3$ RDF+GM+AZOS)	25.58	28.14	26.86	48.67	47.97	48.32	2.02	1.90	1.96	26.00	28.00	27.00
T ₁₃ ($1/2$ RDF+GM+AZOS)	24.72	27.22	25.97	48.62	47.55	48.09	1.63	1.79	1.71	26.33	28.33	27.33
General Mean	26.88	27.90		48.78	48.45		1.88	1.82		27.72	28.44	
S.Em	1.26	1.42		0.47	0.90		0.07	0.06		1.42	0.96	
C.D (0.05)	NS	NS		NS	NS		NS	NS		NS	NS	

30.29 per cent (T7) with an average of 27.90 per cent during 2003-04. However, the effect of different INM treatments on starch content of cassava was noticed to be non-significant (Fig.5).

4.1.14.2 Hydrocyanin content (HCN)

The HCN content of cassava tuber was in general observed to be higher during 2002-03 (48.78 $\mu\text{g/g}$), compared to 2003-04 (48.45 $\mu\text{g/g}$). Further, the hydrocyanin content was observed to range from 47.29 $\mu\text{g/g}$ (T1) to 49.84 $\mu\text{g/g}$ (T7) during 2002-03; and 46.36 $\mu\text{g/g}$ (T1) to 49.88 $\mu\text{g/g}$ (T2) during 2003-04. However, the influence of different INM treatments on HCN content of cassava tubers was observed to be non-significant during both the years of investigation (Fig.5).

4.1.14.3 Crude fibre content

Crude fibre content of cassava tuber was observed to be in the range from 1.63 per cent (T13) to 2.03 per cent (T10) with an average of 1.88 per cent during 2002-03; and from 1.62 per cent (T5) to 1.91 per cent (T9) with an average of 1.82 per cent during 2003-04. However, the effect of different INM treatments on crude fibre content of cassava tubers was observed to be non-significant.

4.1.14.4 Cooking time

Cooking time of the tubers was observed to range from 25.0 (T5) to 30.67 (T7) minutes with an average of 27.72 minutes during 2002-03; and from 27.33 (T2) to 29.67 (T10) minutes with an average of 28.44 minutes during 2003-04. However, the effect of different INM treatments on cooking time of cassava tuber was observed to be non-significant.

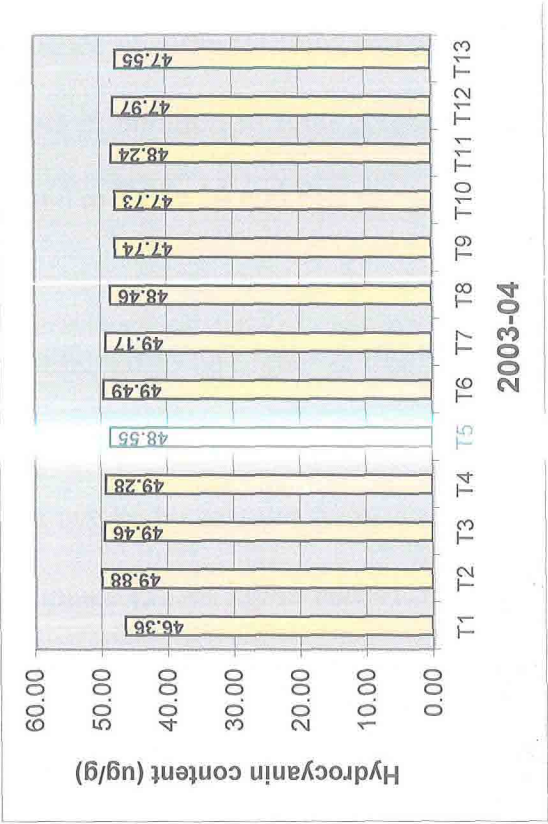
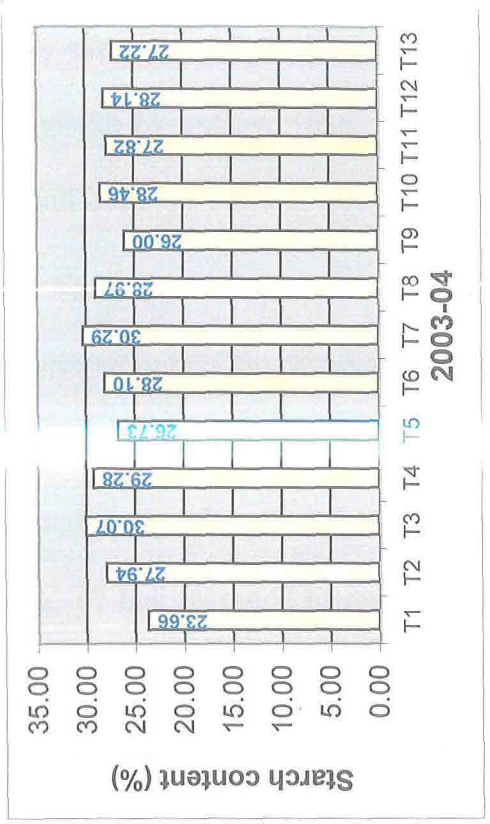
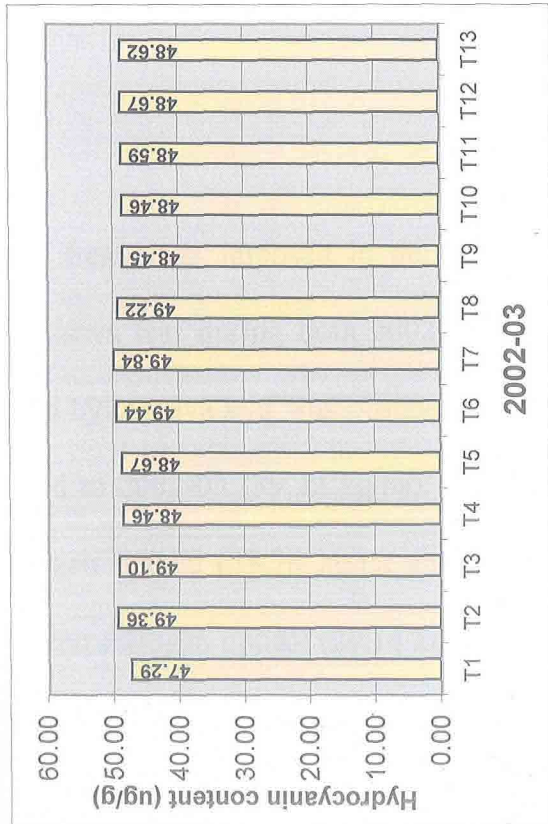
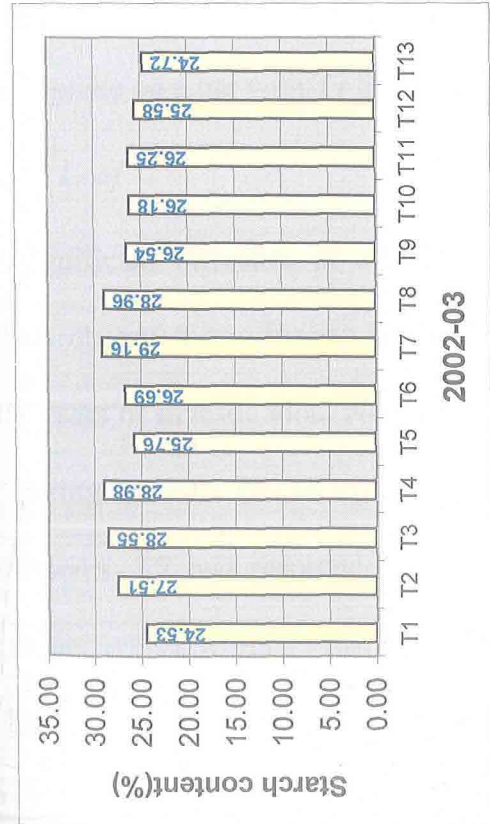


Fig. 5. Quality attributes of cassava as influenced by integrated nutrient management under rainfed conditions

4.1.15 Nitrogen uptake

The experimental results regarding influence of different INM treatments on nitrogen uptake by cassava stem, leaf and tuber in addition to total uptake during 2002-03 and 2003-04 years of study are presented in Table 14 and Fig. 6.

4.1.15.1 Stem

Nitrogen uptake by cassava stem was observed to be higher during 2003-04 (36.43 kg/ha), compared to 2002-03 (31.12 kg/ha). Further, the INM treatments were noticed to significantly influence nitrogen uptake by cassava stem. Among the treatments, T7 had recorded highest nitrogen uptake (37.44 kg/ha and 41.55 kg/ha, respectively), while T1 had recorded lowest nitrogen uptake (22.90 kg/ha and 30.19 kg/ha, respectively) during 2002-03 and 2003-04. The treatments, T6 (36.25 kg/ha), T8 (36.47 kg/ha) and T9 (35.82 kg/ha) during 2002-03; and T3 (39.46 kg/ha), T6 (40.28 kg/ha), T8 (40.36 kg/ha) and T9 (39.24 kg/ha) during 2003-04 had recorded nitrogen uptake on a par with T7 treatment.

4.1.15.2 Leaf

Significant influence of different INM treatments imposed in the present study was observed on nitrogen uptake by cassava leaf during both 2002-03 and 2003-04 years of investigation. Nitrogen uptake by cassava leaf was observed to be higher during 2003-04 (39.81 kg/ha), compared to 2002-03 (39.32 kg/ha). Among the treatments, T7 had recorded highest nitrogen uptake (43.76 kg/ha and 46.69 kg/ha, respectively), while T1 had recorded lowest nitrogen uptake (29.14 kg/ha and 34.05 kg/ha, respectively) during 2002-03 and 2003-04. The treatments, T2 (40.92 kg/ha), T3 (42.31 kg/ha), T4 (41.76 kg/ha), T5 (39.80 kg/ha), T6 (41.14 kg/ha), T8

Table 14 : Nitrogen uptake (kg/ha) in cassava as influenced by integrated nutrient management under rainfed conditions

Treatments	Stem			Leaf			Tuber			Total uptake		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	22.90	30.19	26.55	29.14	34.05	31.60	16.43	19.35	17.89	68.47	83.59
T ₂ (RDF+FYM)	31.44	36.52	33.98	40.92	38.54	39.73	21.77	26.48	24.13	94.13	101.54	97.84
T ₃ (RDF+FYM+AZOS)	32.51	39.46	35.99	42.31	41.87	42.09	32.89	33.48	33.19	107.71	114.81	111.26
T ₄ (1/3 RDF+FYM+AZOS)	31.90	36.09	34.00	41.76	39.24	40.50	31.84	32.05	31.95	105.50	107.38	106.44
T ₅ (1/2 RDF+FYM+AZOS)	30.57	35.72	33.15	39.80	36.95	38.38	20.36	25.81	23.09	90.73	98.48	94.61
T ₆ (RDF+VC)	36.25	40.28	38.27	41.14	43.42	42.28	31.28	32.94	32.11	108.67	116.64	112.66
T ₇ (RDF+VC+AZOS)	37.44	41.55	39.50	43.76	46.69	45.23	37.30	41.43	39.37	118.50	129.67	124.09
T ₈ (1/3 RDF+VC+AZOS)	36.47	40.36	38.42	42.15	44.87	43.51	35.65	37.96	36.81	114.27	123.19	118.73
T ₉ (1/2 RDF+VC+AZOS)	35.82	39.24	37.53	41.86	40.35	41.11	29.86	31.87	30.87	107.54	111.46	109.50
T ₁₀ (RDF+GM)	28.11	33.32	30.72	36.39	38.02	37.21	20.89	25.50	23.20	85.39	96.84	91.12
T ₁₁ (RDF+GM+AZOS)	27.87	34.52	31.20	39.62	40.66	40.14	24.96	30.33	27.65	92.45	105.51	98.98
T ₁₂ (1/3 RDF+GM+AZOS)	27.38	33.94	30.66	37.81	37.69	37.75	23.60	28.77	26.19	88.79	100.40	94.60
T ₁₃ (1/2 RDF+GM+AZOS)	25.94	32.42	29.18	34.53	35.24	34.89	21.36	23.42	22.39	81.83	91.08	86.46
General Mean	31.12	36.43		39.32	39.81		26.78	29.95		97.23	106.20	
S.Em	1.21	1.61		3.05	3.34		3.82	4.62		3.33	3.29	
C.D (0.05)	3.53	4.70		8.90	9.75		11.16	13.48		9.71	9.59	

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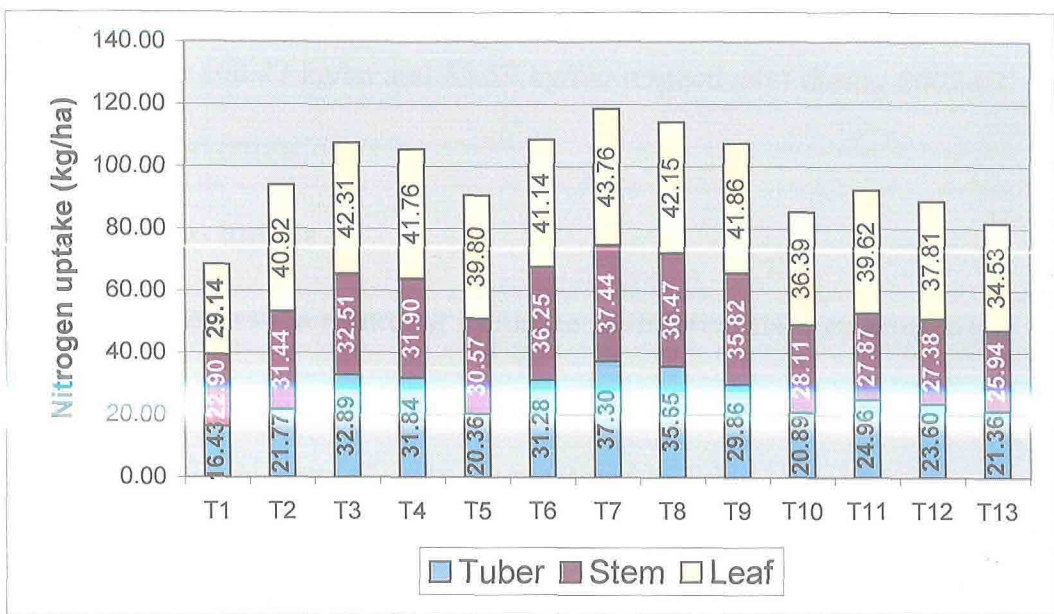
(42.15 kg/ha), T9 (41.86 kg/ha), T10 (36.39 kg/ha), T11 (39.62 kg/ha) and T12 (37.81 kg/ha) during 2002-03; and T2 (38.54 kg/ha), T3 (41.87 kg/ha), T4 (39.24 kg/ha), T5 (36.95 kg/ha), T6 (43.42 kg/ha), T8 (44.87 kg/ha), T9 (40.43 kg/ha), T10 (38.02 kg/ha), T11 (40.66 kg/ha) and T12 (37.69 kg/ha) during 2003-04 had recorded nitrogen uptake on a par with T7 treatment.

4.1.15.3 Tuber

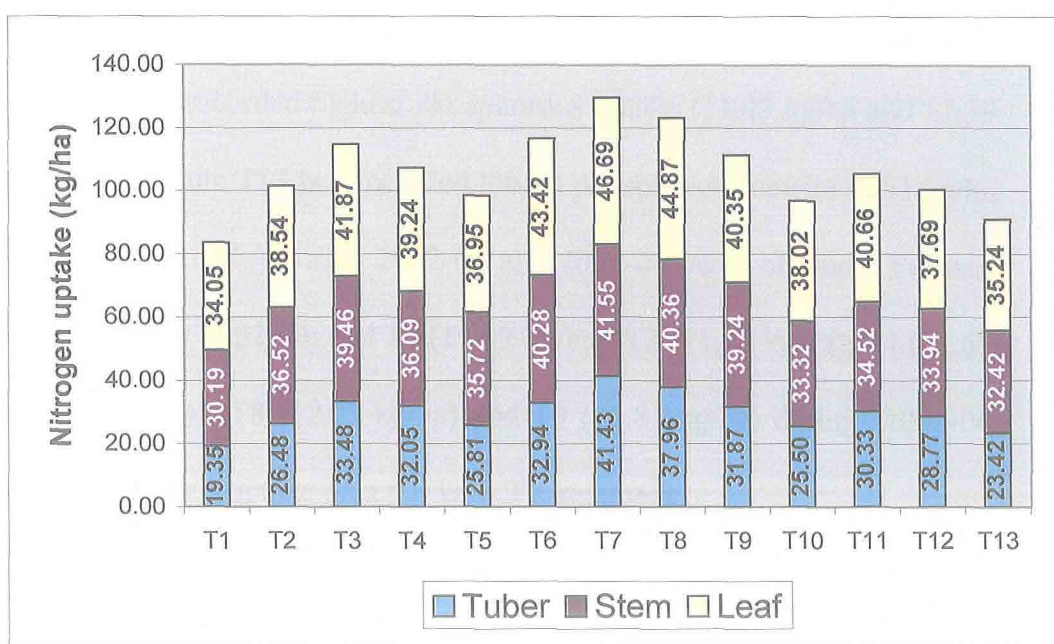
The different INM treatments studied in the present investigation were observed to exert a significant influence on the nitrogen uptake by cassava tuber during both 2002-03 and 2003-04 years of investigation. Higher nitrogen uptake by cassava tuber was noticed during 2003-04 (29.95 kg/ha), compared to 2002-03 (26.78 kg/ha). Among the treatments, T7 had recorded highest nitrogen uptake (37.30 kg/ha and 41.43 kg/ha, respectively), while T1 had recorded lowest nitrogen uptake (16.43 kg/ha and 19.35 kg/ha, respectively) during 2002-03 and 2003-04. The treatments, T3 (32.89 kg/ha), T4 (31.84 kg/ha), T6 (31.28 kg/ha), T8 (35.65 kg/ha) and T9 (29.86 kg/ha) during 2002-03; and T3 (33.48 kg/ha), T4 (32.05 kg/ha), T6 (32.94 kg/ha), T8 (37.96 kg/ha), T9 (31.87 kg/ha), T11 (30.33 kg/ha) and T12 (28.77 kg/ha) during 2003-04 had recorded nitrogen uptake on a par with T7 treatment.

4.1.15.4 Total

A significant influence of different INM treatments studied was observed on total nitrogen uptake by cassava during both 2002-03 and 2003-04 years of investigation. Higher uptake was recorded during 2003-04 (106.20 kg/ha), compared to 2002-03 (97.23 kg/ha). Among the treatments, T7 had recorded highest nitrogen



2002-03



2003-04

Fig.6. Nitrogen uptake (kg/ha) in cassava as influenced by integrated nutrient management under rainfed conditions

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uptake (118.50 kg/ha and 129.67 kg/ha, respectively), followed by T8 treatment (114.27 kg/ha and 123.19 kg/ha, respectively), while T1 treatment had recorded lowest nitrogen uptake (68.47 kg/ha and 83.59 kg/ha, respectively) during 2002-03 and 2003-04 years of investigation.

4.1.16 Phosphorous uptake

The experimental results regarding influence of different INM treatments on phosphorous uptake by cassava stem, leaf and tuber in addition to total uptake during 2002-03 and 2003-04 years of study are presented in Table 15 and Fig.7.

4.1.16.1 Stem

Phosphorous uptake by cassava stem was observed to be significantly influenced by the different INM treatments. Higher phosphorous uptake was recorded during 2003-04 (11.10 kg/ha), compared to 2002-03 (9.71 kg/ha). Among the treatments, T7 had recorded highest phosphorous uptake (11.43 kg/ha and 12.39 kg/ha, respectively), while T13 had recorded lowest phosphorous uptake (8.51 kg/ha and 9.23 kg/ha, respectively) during 2002-03 and 2003-04 years of study. Further, T6 (11.40 kg/ha) during 2002-03; and T2 (11.97 kg/ha), T3 (11.83 kg/ha), T4 (11.61 kg/ha), T6 (12.25 kg/ha), T8 (12.03 kg/ha) and T9 (11.81 kg/ha) during 2003-04 had recorded phosphorous uptake on a par with T7 treatment.

4.1.16.2 Leaf

A significant influence of the different INM treatments imposed in the present investigation was recorded on phosphorous uptake by cassava leaf during both 2002-03 and 2003-04 years of investigation. Higher phosphorous uptake by cassava leaf was recorded during 2003-04 (7.68 kg/ha), compared to 2002-03

Table 15 : Phosphorous uptake (kg/ha) in cassava as influenced by integrated nutrient management under rainfed conditions

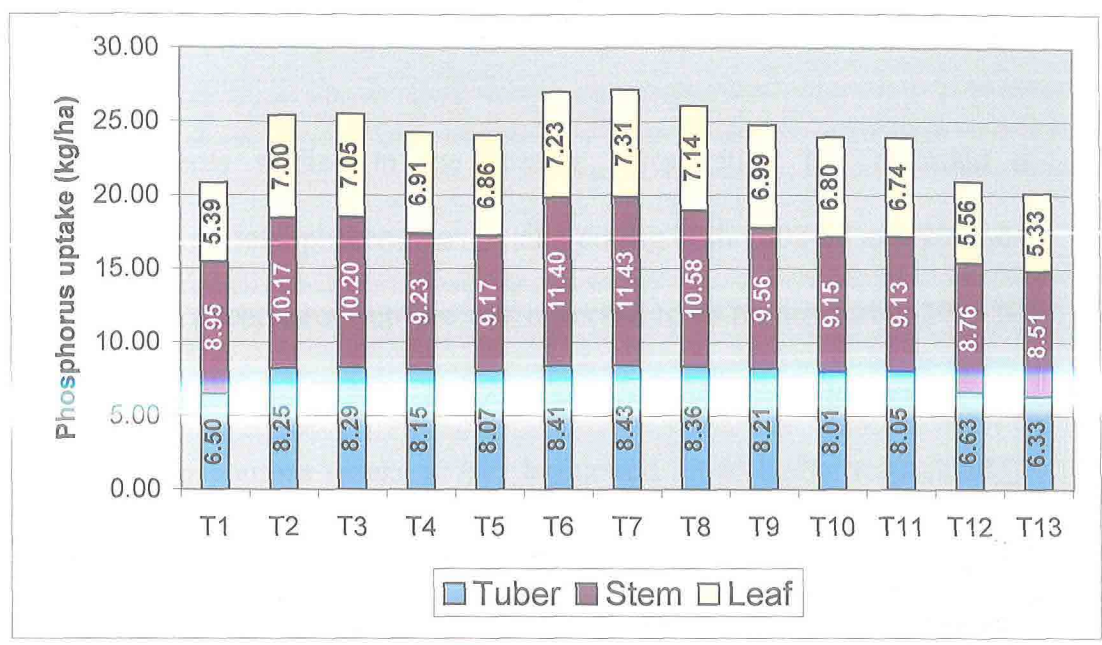
Treatments	Stem			Leaf			Tuber			Total uptake		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	8.95	9.38	9.17	5.39	6.57	5.98	6.50	7.53	7.02	20.84	23.48
T ₂ (RDF+FYM)	10.17	11.97	11.07	7.00	8.07	7.54	8.25	8.32	8.29	25.42	28.36	26.89
T ₃ (RDF+FYM+AZOS)	10.20	11.83	11.02	7.05	8.12	7.59	8.29	8.36	8.33	25.54	28.31	26.93
T ₄ (1/3 RDF+FYM+AZOS)	9.23	11.61	10.42	6.91	7.93	7.42	8.15	8.21	8.18	24.29	27.75	26.02
T ₅ (1/2 RDF+FYM+AZOS)	9.17	11.01	10.09	6.86	7.91	7.39	8.07	8.19	8.13	24.10	27.11	25.61
T ₆ (RDF+VC)	11.40	12.25	11.83	7.23	8.25	7.74	8.41	8.44	8.43	27.04	28.94	27.99
T ₇ (RDF+VC+AZOS)	11.43	12.39	11.91	7.31	8.32	7.82	8.43	8.69	8.56	27.17	29.40	28.29
T ₈ (1/3 RDF+VC+AZOS)	10.58	12.03	11.31	7.14	8.21	7.68	8.36	8.41	8.39	26.08	28.65	27.37
T ₉ (1/2 RDF+VC+AZOS)	9.56	11.81	10.69	6.99	7.98	7.49	8.21	8.25	8.23	24.76	28.04	26.40
T ₁₀ (RDF+GM)	9.15	10.99	10.07	6.80	7.87	7.34	8.01	8.12	8.07	23.96	26.98	25.47
T ₁₁ (RDF+GM+AZOS)	9.13	10.52	9.83	6.74	7.58	7.16	8.05	8.09	8.07	23.92	26.19	25.06
T ₁₂ (1/3 RDF+GM+AZOS)	8.76	9.30	9.03	5.56	6.69	6.13	6.63	7.64	7.14	20.95	23.63	22.29
T ₁₃ (1/2 RDF+GM+AZOS)	8.51	9.23	8.87	5.33	6.29	5.81	6.33	7.28	6.81	20.17	22.80	21.49
General Mean	9.71	11.10		6.64	7.68		7.82	8.12		24.17	26.90	
S.E.m	0.20	0.32		0.27	0.29		0.24	0.26		0.77	0.95	
C.D (0.05)	0.59	0.94		0.79	0.85		0.70	0.76		2.25	2.78	

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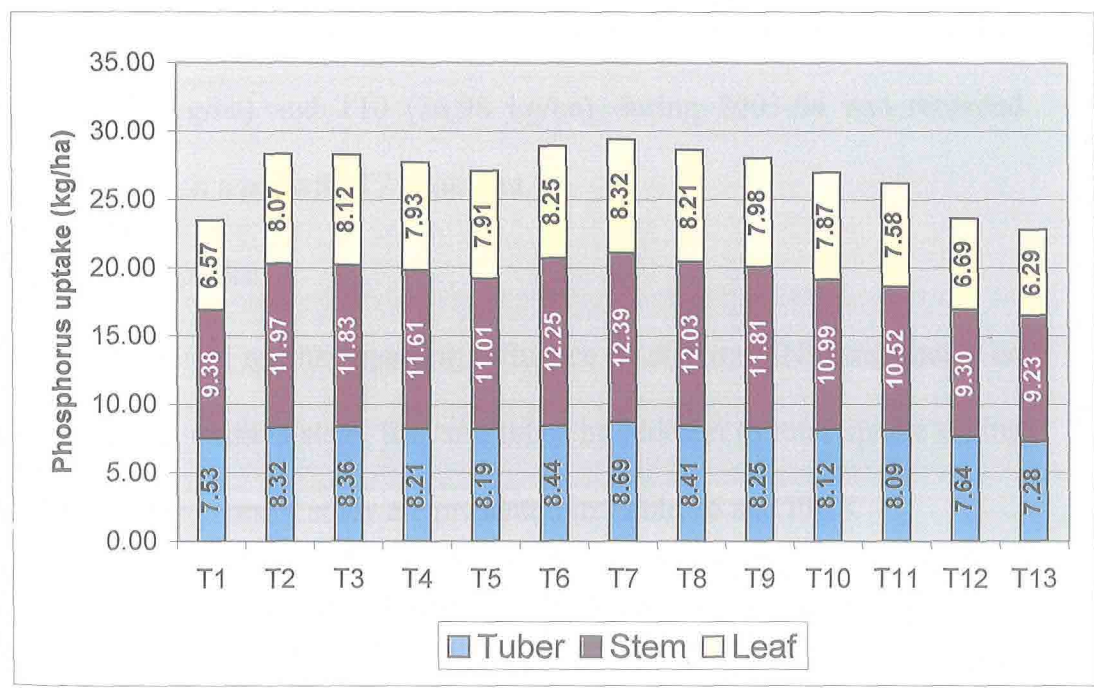
(6.64 kg/ha). Among the treatments, T7 had recorded highest uptake (7.31 kg/ha and 8.32 kg/ha, respectively), while T13 had recorded lowest uptake (5.33 kg/ha and 6.29 kg/ha, respectively) during 2002-03 and 2003-04. Further, T2 (7.00 kg/ha and 8.07 kg/ha, respectively), T3 (7.05 kg/ha and 8.12 kg/ha, respectively), T4 (6.91 kg/ha and 7.93 kg/ha, respectively), T5 (6.86 kg/ha and 7.91 kg/ha, respectively), T6 (7.23 kg/ha and 8.25 kg/ha, respectively), T8 (7.14 kg/ha and 8.21 kg/ha, respectively), T9 (6.99 kg/ha and 7.98 kg/ha, respectively), T10 (6.80 kg/ha and 7.87 kg/ha, respectively) and T11 (6.74 kg/ha and 7.58 kg/ha, respectively) had recorded phosphorous uptake on a par with T7 treatment during 2002-03 and 2003-04 years of study.

4.1.16.3 Tuber

INM treatments studied in the present investigation had exerted significant influence on phosphorous uptake by cassava tuber during both 2002-03 and 2003-04 years of investigation. Higher phosphorous uptake was observed during 2003-04 (8.12 kg/ha), compared to 2002-03 (7.82 kg/ha). Among the treatments, T7 had recorded highest uptake (8.43 kg/ha and 8.69 kg/ha, respectively), while T13 had recorded lowest uptake (6.33 kg/ha and 7.28 kg/ha, respectively) during both 2002-03 and 2003-04 years of investigation. Further, T2 (8.25 kg/ha and 8.32 kg/ha, respectively), T3 (8.29 kg/ha and 8.36 kg/ha, respectively), T4 (8.15 kg/ha and 8.21 kg/ha, respectively), T5 (8.07 kg/ha and 8.19 kg/ha, respectively), T6 (8.41 kg/ha and 8.44 kg/ha, respectively), T8 (8.36 kg/ha and 8.41 kg/ha, respectively), T9 (8.21 kg/ha and 8.25 kg/ha, respectively), T10 (8.01 kg/ha and 8.12 kg/ha, respectively)



2002-03



2003-04

Fig. 7. Phosphorus uptake (kg/ha) in cassava as influenced by integrated nutrient management under rainfed conditions

and T11 (8.05 kg/ha and 8.09 kg/ha, respectively) had recorded phosphorous uptake on a par with T7 treatment during 2002-03 and 2003-04 years of study.

4.1.16.4 Total

INM treatments studied in the present investigation had recorded a significant influence on total phosphorous uptake during both 2002-03 and 2003-04 years of study. Total phosphorous uptake was observed to be higher during 2003-04 (26.90 kg/ha), compared to 2002-03 (24.17 kg/ha). Among the treatments, T7 had recorded highest phosphorous uptake (27.17 kg/ha and 29.40 kg/ha, respectively), while T13 had recorded lowest uptake (20.17 kg/ha and 22.80 kg/ha, respectively) during both 2002-03 and 2003-04. Further, T2 (25.42 kg/ha), T3 (25.54 kg/ha), T6 (27.04 kg/ha) and T8 (26.08 kg/ha) during 2002-03; and T2 (28.36 kg/ha), T3 (28.31 kg/ha), T4 (27.75 kg/ha), T5 (27.11 kg/ha), T7 (28.94 kg/ha), T8 (28.65 kg/ha), T9 (28.04 kg/ha) and T10 (26.98 kg/ha) during 2003-04 had recorded phosphorous uptake on a par with T7 treatment.

4.1.17 Potassium uptake

The experimental results regarding influence of different INM treatments on potassium uptake by cassava stem, leaf and tuber in addition to total uptake during 2002-03 and 2003-04 years of study are presented in Table 16 and Fig.8.

4.1.17.1 Stem

The INM treatments had exerted a significant influence on potassium uptake by cassava stem during 2002-03 and 2003-04 years of investigation. Higher potassium uptake was noticed during 2003-04 (29.02 kg/ha), compared to 2002-03 (28.21 kg/ha). Among the treatments, T7 had recorded highest potassium uptake

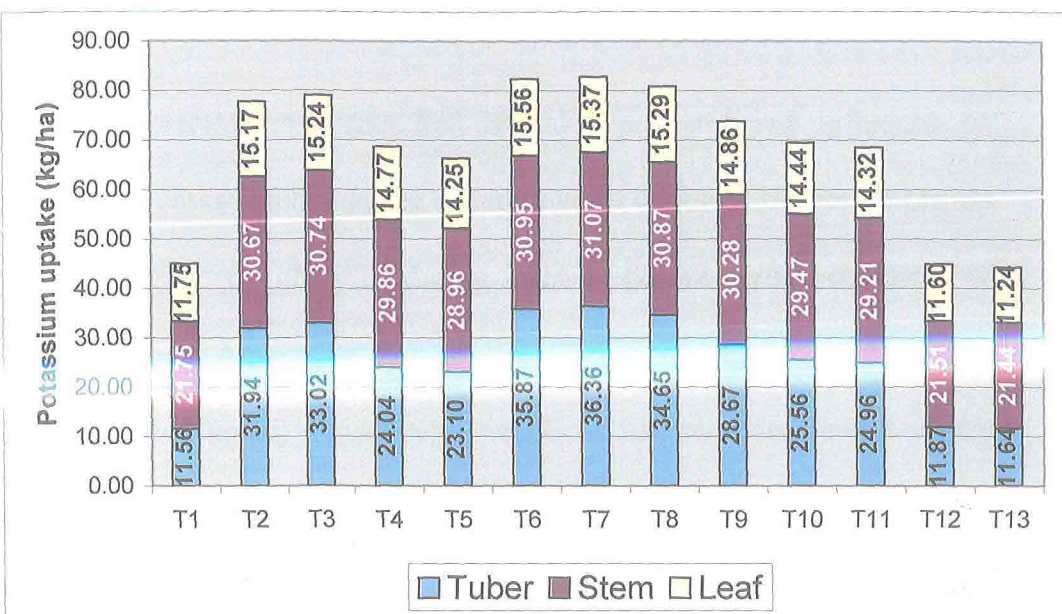
Table 16 : Potassium uptake (kg/ha) in cassava as influenced by integrated nutrient management under rainfed conditions

Treatments	Stem				Leaf				Tuber				Total uptake		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	21.75	21.78	21.77	11.75	11.87	11.81	11.56	13.01	12.29	45.06	46.66	45.86		
T ₂ (RDF+FYM)	30.67	31.35	31.01	15.17	15.38	15.28	31.94	36.19	34.07	77.78	82.92	80.35			
T ₃ (RDF+FYM+AZOS)	30.74	31.20	30.97	15.24	15.43	15.34	33.02	36.35	34.69	79.00	82.98	80.99			
T ₄ (² / ₃ RDF+FYM+AZOS)	29.86	31.01	30.44	14.77	15.07	14.92	24.04	29.17	26.61	68.67	75.25	71.96			
T ₅ (¹ / ₂ RDF+FYM+AZOS)	28.96	30.73	29.85	14.25	14.74	14.50	23.10	25.65	24.38	66.31	71.12	68.72			
T ₆ (RDF+VC)	30.95	31.75	31.35	15.56	16.02	15.79	35.87	39.51	37.69	82.38	87.28	84.83			
T ₇ (RDF+VC+AZOS)	31.07	31.82	31.45	15.37	16.17	15.77	36.36	41.48	38.92	82.80	89.47	86.14			
T ₈ (² / ₃ RDF+VC+AZOS)	30.87	31.54	31.21	15.29	15.98	15.64	34.65	38.11	36.38	80.81	85.63	83.22			
T ₉ (¹ / ₂ RDF+VC+AZOS)	30.28	31.14	30.71	14.86	15.14	15.00	28.67	31.29	29.98	73.81	77.57	75.69			
T ₁₀ (RDF+GM)	29.47	30.97	30.22	14.44	14.86	14.65	25.56	28.31	26.94	69.47	74.14	71.81			
T ₁₁ (RDF+GM+AZOS)	29.21	30.82	30.02	14.32	14.82	14.57	24.96	27.54	26.35	68.49	73.18	70.84			
T ₁₂ (² / ₃ RDF+GM+AZOS)	21.51	21.64	21.58	11.60	11.82	11.71	11.87	14.84	13.36	44.98	48.30	46.64			
T ₁₃ (¹ / ₂ RDF+GM+AZOS)	21.44	21.57	21.51	11.24	11.69	11.47	11.64	13.15	12.40	44.32	46.41	45.37			
General Mean	28.21	29.02		14.14	14.54		25.63	28.82		67.99	72.38				
S.Em	1.97	2.02		1.17	1.31		3.41	3.71		3.25	3.68				
C.D (0.05)	5.76	5.91		3.42	3.83		9.95	10.83		9.50	10.74				

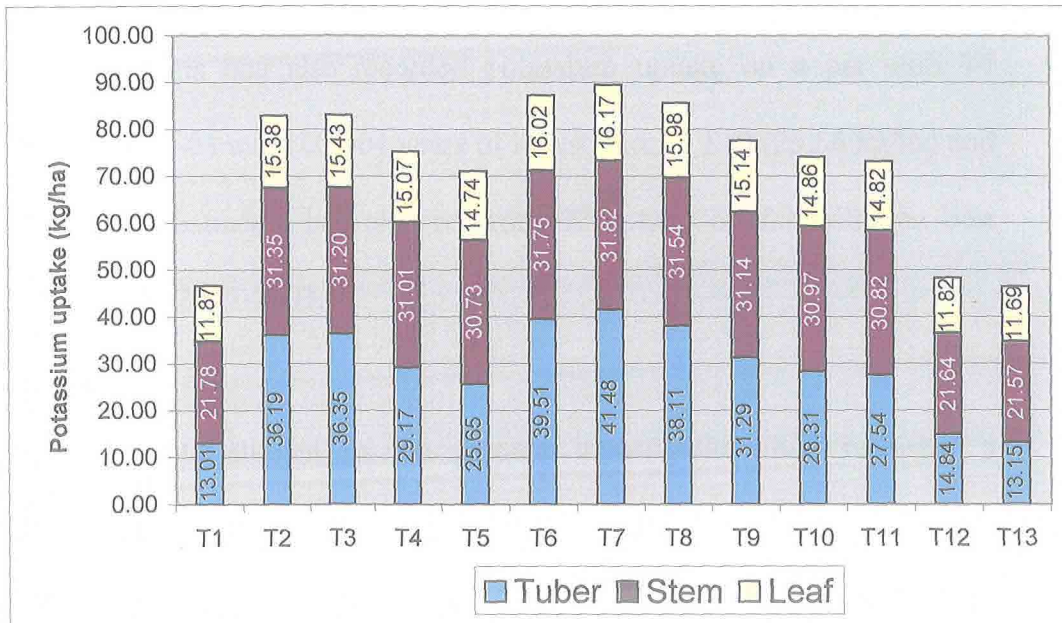
(31.07 kg/ha and 31.82 kg/ha, respectively), while T13 had recorded lowest potassium uptake (21.44 kg/ha and 21.57 kg/ha, respectively) during 2002-03 and 2003-04 years of study. Further, T2 (30.67 kg/ha and 31.35 kg/ha, respectively), T3 (30.74 kg/ha and 31.20 kg/ha, respectively), T4 (29.86 kg/ha and 31.01 kg/ha, respectively), T5 (28.96 kg/ha and 30.73 kg/ha, respectively), T6 (30.95 kg/ha and 31.75 kg/ha, respectively), T8 (30.87 kg/ha and 31.54 kg/ha, respectively), T9 (30.28 kg/ha and 31.14 kg/ha, respectively), T10 (29.47 kg/ha and 30.97 kg/ha, respectively) and T11 (29.21 kg/ha and 30.82 kg/ha, respectively) had recorded potassium uptake on a par with T7 treatment during both 2002-03 and 2003-04 years of investigation.

4.1.17.2 Leaf

The significant influence of INM treatments studied in the present investigation was noticed on potassium uptake by cassava leaf during both 2002-03 and 2003-04 years of study. Potassium uptake by cassava leaf was observed to be higher during 2003-04 (14.54 kg/ha), compared to 2002-03 (14.14 kg/ha). Among the treatments, T6 (15.56 kg/ha) during 2002-03 and T7 (16.17 kg/ha) during 2003-04 had recorded highest potassium uptake, while T13 treatment had recorded lowest uptake (11.24 kg/ha and 11.69 kg/ha, respectively) during 2002-03 and 2003-04 years of investigation. Further, the treatments, T2 (15.17 kg/ha), T3 (15.24 kg/ha), T4 (14.77 kg/ha), T5 (14.25 kg/ha), T7 (15.37 kg/ha), T8 (15.29 kg/ha), T9 (14.86 kg/ha), T10 (14.44 kg/ha) and T11 (14.32 kg/ha) had recorded potassium uptake on a par with T6 treatment during 2002-03, while T2 (15.38 kg/ha), T3 (15.43 kg/ha), T4 (15.07 kg/ha), T5 (14.74 kg/ha), T6 (16.02 kg/ha), T8 (15.98



2002-03



2003-04

Fig. 8. Potassium uptake (kg/ha) in cassava as influenced by integrated nutrient management under rainfed conditions

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kg/ha), T9 (15.14 kg/ha), T10 (14.86 kg/ha) and T11 (14.82 kg/ha) treatments had recorded potassium uptake on a par with T7 treatment during 2003-04.

4.1.17.3 Tuber

The different INM treatments had recorded a significant influence on potassium uptake by cassava tuber during different years of study. Higher potassium uptake by cassava tuber was observed during 2003-04 (28.82 kg/ha), compared to 2002-03 (25.63 kg/ha). Among the treatments, T7 had recorded highest uptake (36.36 kg/ha and 41.48 kg/ha, respectively), while T1 had recorded lowest uptake (11.56 kg/ha and 13.01 kg/ha, respectively) during both 2002-03 and 2003-04 years of study. Further, T2 (31.94 kg/ha and 36.19 kg/ha, respectively), T3 (33.02 kg/ha and 36.35 kg/ha, respectively), T6 (35.87 kg/ha and 39.51 kg/ha, respectively), T8 (34.65 kg/ha and 38.11 kg/ha, respectively) and T9 (28.67 kg/ha and 31.29 kg/ha, respectively) treatments had also recorded potassium uptake on a par with T7 treatment during 2002-03 and 2003-04 years of investigation. T10 (25.56 kg/ha) and T11 (24.96 kg/ha) treatments had also recorded K uptake on par with the best treatment (T7) during 2002-2003.

4.1.17.4 Total

INM treatments studied in the present investigation had recorded a significant influence on total potassium uptake by cassava during 2002-03 and 2003-04 years of investigation. Further, 2003-04 had recorded higher uptake (72.38 kg/ha), compared to 2002-03 (67.99 kg/ha) year of study. Among the different INM treatments studied, T7 had recorded highest uptake (82.80 kg/ha and 89.47 kg/ha, respectively), while T13 had recorded lowest uptake (44.32 kg/ha and 46.41 kg/ha,

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respectively) during both 2002-03 and 2003-04. Further, the treatments, T2 (77.78 kg/ha), T3 (79.00 kg/ha), T6 (82.38 kg/ha), T8 (80.81 kg/ha) and T9 (73.81 kg/ha) during 2002-03; and T2 (82.92 kg/ha), T3 (82.98 kg/ha), T6 (87.28 kg/ha) and T8 (85.63 kg/ha) during 2003-04 had recorded total potassium uptake on a par with T7 treatment.

4.1.18 Correlation studies

The correlation studies between growth and yield attributes, nutrient uptake and yield of cassava under rain fed condition are presented in Tables 16a and 16b.

The data revealed that tuber yield of cassava was positively and significantly correlated with growth attributes namely plant height (0.937** and 0.952**, respectively), stem girth (0.714** and 0.946**, respectively), leaves per plant (0.680** and 0.970**, respectively), leaf area index (0.658* and 0.943**, respectively), total dry matter (0.900** and 0.946**, respectively), and growth analysis parameters like CGR (0.736** and 0.714**, respectively), and NAR (0.636** and 0.641**, respectively), and yield attributes namely tubers per plant (0.866** and 0.689**, respectively), tuber length (0.823** and 0.566*, respectively), tuber girth (0.867** and 0.602**, respectively), and nutrient uptake such as N (0.636* and 0.745**, respectively), P uptake (0.704** and 0.665**, respectively), and K uptake (0.831** and 0.826**, respectively) during both 2002-03 and 2003-04 years of study.

4.1.19 Cost of cultivation

The cost of cultivation, gross and net returns in addition to benefit : cost ratio of different INM treatments studied in the present investigation are presented in Table 17 and Figs. 9 and 10.

Table 16a : Correlation matrix between growth and yield attributes, nutrient uptake and yield of cassava under rainfed conditions during 2002-03

	Plant height	Stem girth	Leaves plant ⁻¹	Leaf area index	Total dry matter	CGR	NAR	Tubers plant ⁻¹	Tuber length	Tuber diameter	N Uptake	P Uptake	K Uptake	Yield ha ⁻¹
Plant height	1.000	0.852**	0.764**	0.737**	0.961**	0.751**	0.654*	0.937**	0.865**	0.858**	0.571*	0.694**	0.821**	0.937**
Stem girth		1.000	0.862**	0.843**	0.852**	0.548	0.435	0.722**	0.809**	0.676**	0.495	0.532	0.609*	0.714**
Leaves plant ⁻¹			1.000	0.935**	0.881**	0.692**	0.700**	0.725**	0.830**	0.752**	0.697**	0.539	0.670*	0.680*
Leaf area index				1.000	0.834**	0.641*	0.628*	0.651*	0.796**	0.679*	0.709**	0.431	0.648*	0.658*
Total dry matter					1.000	0.648*	0.702**	0.940**	0.907**	0.852**	0.716**	0.729**	0.783**	0.900**
CGR						1.000	0.911**	0.698**	0.615*	0.505	0.650*	0.592*	0.643*	0.736**
NAR							1.000	0.416	0.274	0.685**	0.670*	0.563*	0.664*	0.636*
Tubers plant ⁻¹								1.000	0.849**	0.856**	0.655*	0.747**	0.768**	0.866**
Tuber length									1.000	0.835**	0.629*	0.636*	0.700**	0.823**
Tuber girth										1.000	0.634*	0.733**	0.901**	0.867**
N Uptake											1.000	0.610**	0.613**	0.636*
P Uptake												1.000	0.660*	0.704*
K Uptake													1.000	0.831**
Yield ha ⁻¹														1.000

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 16b : Correlation matrix between growth and yield attributes, nutrient uptake and yield of cassava under rainfed conditions during 2003-04

	Plant height	Stem girth	Leaves plant ⁻¹	Leaf area index	Total dry matter	CGR	NAR	Tubers plant ⁻¹	Tuber length	Tuber diameter	N Uptake	P Uptake	K Uptake	Yield ha ⁻¹
Plant height	1.000	0.921**	0.926**	0.857**	0.959**	0.642*	0.519	0.665*	0.652*	0.631*	0.743**	0.853**	0.952**	
Stem girth		1.000	0.920**	0.862**	0.960**	0.539	0.426	0.839**	0.614*	0.537*	0.735**	0.793**	0.946**	
Leaves plant ⁻¹			1.000	0.960**	0.950**	0.610*	0.664*	0.625*	0.481	0.430	0.811**	0.612*	0.785**	0.970**
Leaf area index				1.000	0.853**	0.567*	0.606*	0.555*	0.479	0.384	0.724**	0.495	0.720**	0.943**
Total dry matter					1.000	0.593*	0.561*	0.737**	0.536	0.344	0.768**	0.743**	0.777**	0.946**
CGR						1.000	0.876**	0.461	0.364	0.486	0.624*	0.654*	0.720**	0.714**
NAR							1.000	0.218	0.430	0.530*	0.566*	0.577*	0.654*	0.641*
Tubers plant ⁻¹								1.000	0.559*	0.457	0.476	0.789**	0.617**	0.639**
Tuber length									1.000	0.321	0.243	0.783**	0.729**	0.566*
Tuber girth										1.000	0.320	0.482	0.580*	0.602*
N Uptake											1.000	0.439	0.602*	0.745**
P Uptake												1.000	0.749**	0.665*
K Uptake													1.000	0.826**
Yield ha ⁻¹														1.000

4.1.19.1 Total expenditure

The total expenditure was observed to range from Rs. 8598/- (T13) to Rs 24771/- (T7) during both the years of investigation (Table 17). In general, treatments involving vermicompost component recorded higher expenditure followed by farm yard manure, compared to the treatments involving green manure component during both the years of study.

4.1.19.2 Gross returns

Gross returns for different INM treatments in the present investigation ranged from Rs 23715/- (T1) to Rs 38118/- (T7) during 2002-03 and from Rs 22503/- (T1) to Rs 35979/- (T7) during 2003-04. The returns were in general observed to be higher for treatments involving vermicompost component, compared to farm yard manure and green manure components.

4.1.19.3 Net returns

Net returns of different INM treatments studied ranged from Rs 9019/- (T1) to Rs 20303/- (T4) during 2002-03 and from Rs 7807/- (T1) to Rs 20001/- (T4) during 2003-04.

4.1.19.4 Benefit: cost ratio

The benefit : cost ratio of different INM treatments studied was observed to range from 1.38 (T6) to 2.86 (T13) during 2002-03 and from 1.32 (T6) to 3.04 (T13) during 2003-04.

Table 17 : Cost of cultivation, returns and benefit:cost ratio of integrated nutrient management in cassava under rainfed conditions

Treatments	Total expenditure (Rs/-)			Gross returns (Rs/-)			Net returns (Rs/-)			Benefit : cost ratio		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	14696	14696	14696	23715	22503	23109	9019	7807	8413	1.61	1.53	1.57
T ₂ (RDF+FYM)	17196	17196	17196	27233	30281	28757	10037	13085	11561	1.58	1.76	1.67
T ₃ (RDF+FYM+AZOS)	17271	17271	17271	34618	33676	34147	17347	16405	16876	2.00	1.95	1.98
T ₄ (² / ₃ RDF+FYM+AZOS)	12372	12372	12372	32675	32373	32524	20303	20001	20152	2.64	2.62	2.63
T ₅ (¹ / ₂ RDF+FYM+AZOS)	9923	9923	9923	26130	28689	27409	16207	18766	17486	2.63	2.89	2.76
T ₆ (RDF+VC)	24696	24696	24696	34058	32637	33347	9362	7941	8651	1.38	1.32	1.35
T ₇ (RDF+VC+AZOS)	24771	24771	24771	38118	35979	37048	13347	11208	12277	1.54	1.45	1.50
T ₈ (² / ₃ RDF+VC+AZOS)	19872	19872	19872	37400	35071	36236	17528	15199	16363	1.88	1.76	1.82
T ₉ (¹ / ₂ RDF+VC+AZOS)	17423	17423	17423	31940	31334	31637	14517	13911	14214	1.83	1.80	1.82
T ₁₀ (RDF+GM)	15871	15871	15871	25255	2070	26663	9384	12199	10792	1.59	1.77	1.68
T ₁₁ (RDF+GM+AZOS)	15946	15946	15946	29035	3176	30105	13089	15230	14159	1.82	1.96	1.89
T ₁₂ (² / ₃ RDF+GM+AZOS)	11047	11047	11047	27250	3926	29088	16203	19879	18041	2.47	2.80	2.63
T ₁₃ (¹ / ₂ RDF+GM+AZOS)	8598	8598	8598	24590	2175	25383	15992	17577	16785	2.86	3.04	2.95

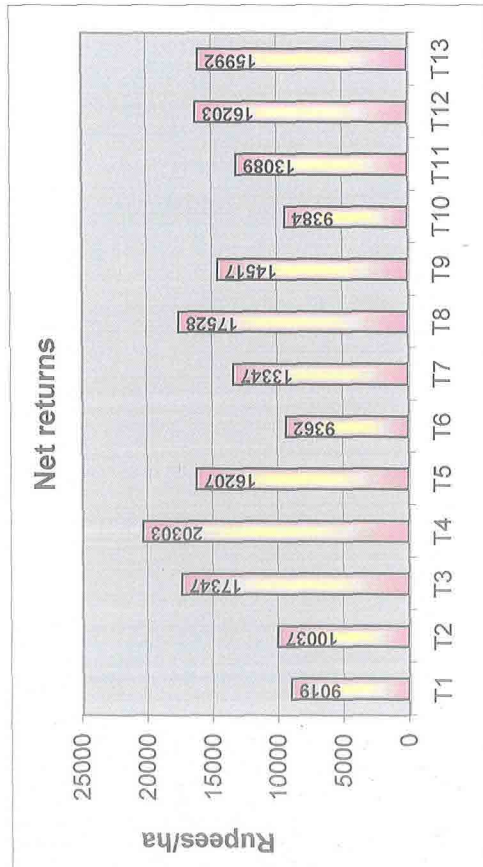
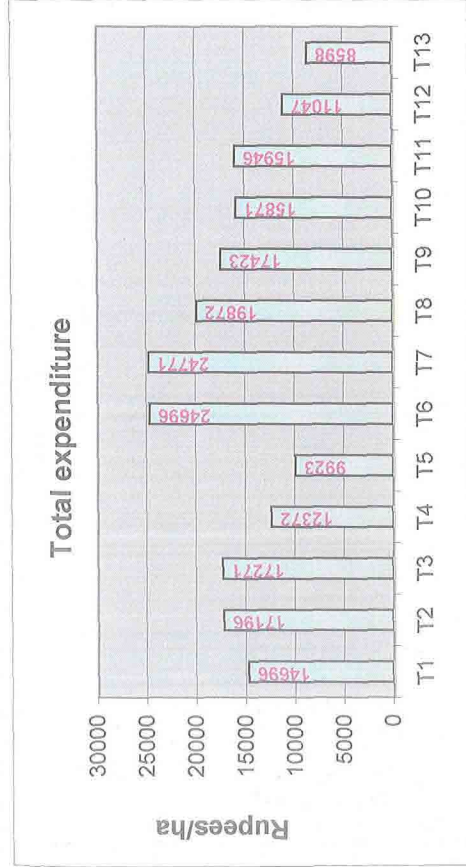
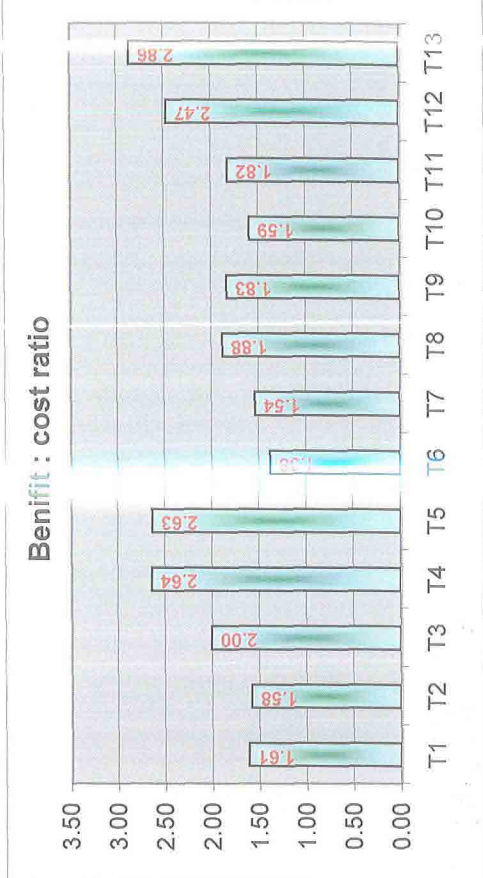
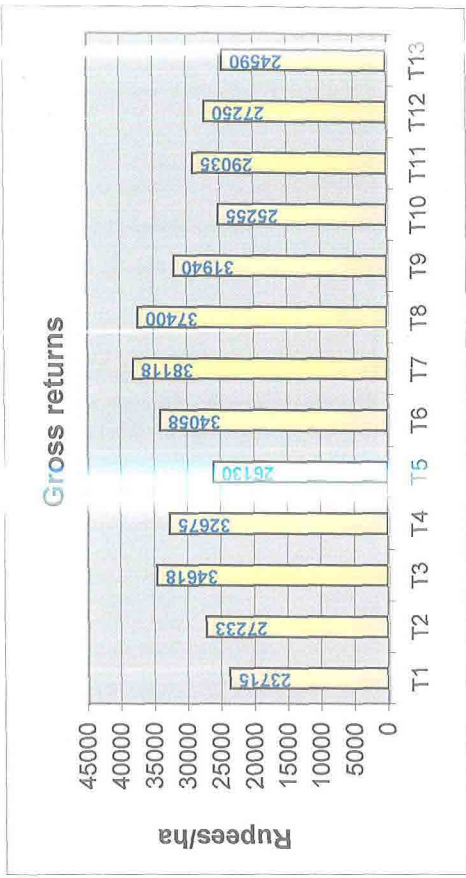


Fig. 9. Cost of cultivation of different integrated nutrient management treatments during 2002-03 under rainfed conditions

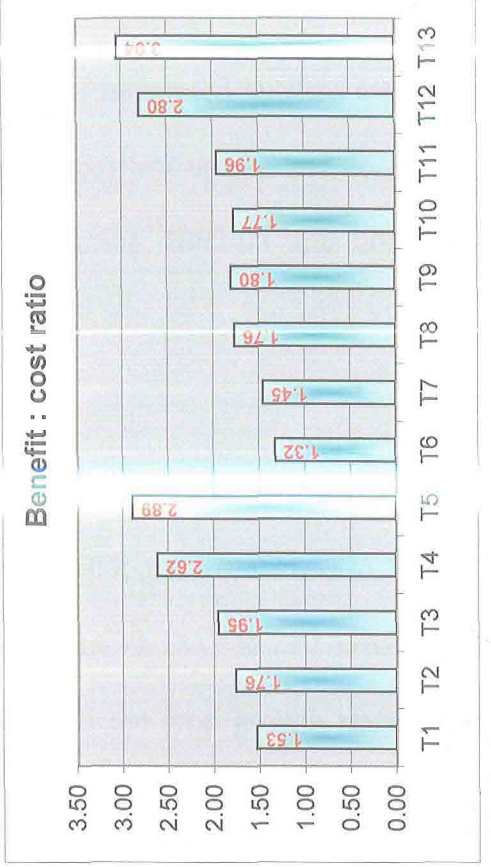
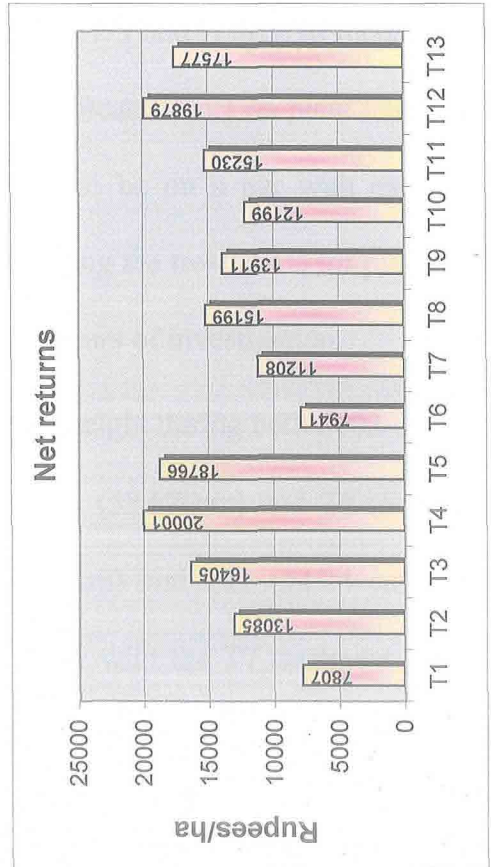
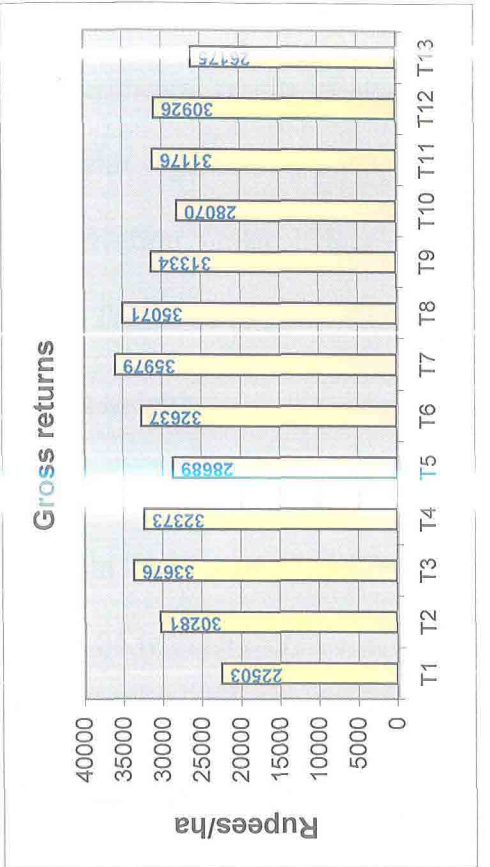
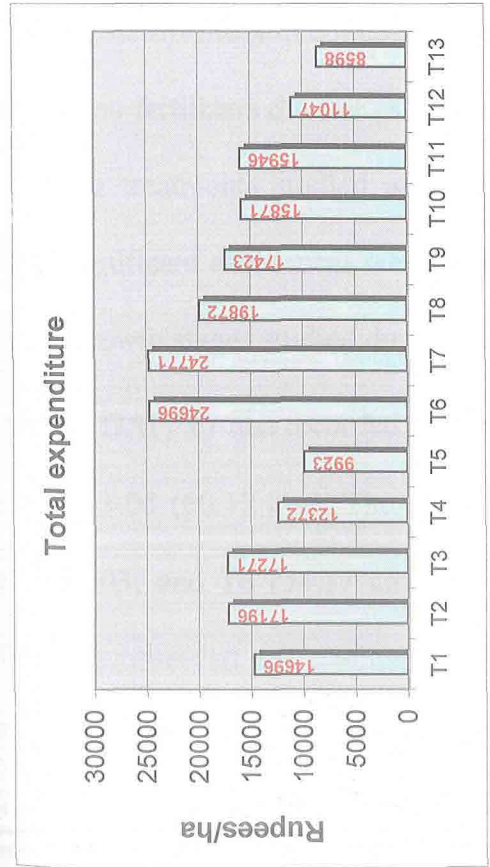


Fig. 10. Cost of cultivation of different integrated nutrient management treatments during 2003-04 under rainfed conditions

4.2 IRRIGATED EXPERIMENT

Experimental results of studies on effect of integrated nutrient management in cassava with regards to growth, yield, quality, nutrient uptake and economics of cost of cultivation under irrigated conditions during 2002-03 and 2003-04 are presented in Tables 18 to 34.

4.2.1 Plant height

The results are presented in Table 18. An increase in plant height was observed from 24.37 cm to 148.27 cm during 2002-03; and from 24.53 to 160.72 cm during 2003-04 with an increase in the crop age from 30 DAP to 210 DAP. Further, greater plant height was in general observed at all the crop growth stages studies during 2003-04, compared to 2002-03.

The application of farm yard manure, vermicompost, green manure and the bio-fertilizer, *Azospirillum* in combination with full, 2/3 and 1/2 dose of recommended NPK inorganic fertilizers did not exhibit any significant effect on plant height at 30 DAP and the treatments studied were observed to be on a par with each other. However, significant differences were noticed among the treatments for plant height at all other growth stages studied during both the years of investigation.

At 60 DAP, T7 had recorded highest plant height during both 2002-03 (55.30 cm) and 2003-04 (60.13 cm). The treatments, T6 (53.67 cm) and T8 (54.13 cm) during 2002-03; and T6 (54.37 cm), T8 (56.75 cm) and T11 (54.24 cm) during 2003-04 were observed to be statistically on a par with the T7 treatment. Further, lowest plant height was recorded by T13 treatment during both the years of study (39.40 cm during 2002-03 and 44.47 cm during 2003-04).

18 : Plant height (cm) as influenced by integrated nutrient management in cassava under irrigated conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	YM)	22.94	23.00	22.97	42.40	46.20	44.30	90.67	90.27	90.47	110.53	120.63	115.58	122.67	133.03	27.85	132.40	143.72	138.06	136.03	146.20
YM+AZOS)	25.10	25.03	25.07	46.97	52.70	49.83	102.00	100.79	101.39	122.27	126.07	124.17	130.20	141.23	35.72	142.80	149.52	146.16	150.33	156.67	153.40
F+FYM+AZOS)	26.41	26.00	26.21	50.03	46.20	48.12	105.40	110.13	107.77	126.40	132.93	129.67	136.10	148.50	42.30	144.00	156.62	150.31	152.53	164.30	158.42
F+FYM+AZOS)	25.09	25.90	25.49	50.10	53.60	51.85	105.33	108.26	106.80	123.73	128.43	126.08	134.07	146.77	40.42	142.03	152.96	147.50	150.13	161.37	155.75
C)	23.81	24.94	24.37	46.60	49.30	47.95	100.60	98.93	99.77	118.27	124.78	121.52	128.93	140.23	34.58	138.30	147.77	143.03	146.00	155.33	150.67
C+AZOS)	25.25	25.70	25.47	53.67	54.37	54.02	108.37	113.07	110.72	130.17	134.79	132.48	136.00	145.07	40.53	146.57	161.47	154.02	154.27	170.83	162.55
F+VC+AZOS)	28.56	27.60	28.08	55.30	60.13	57.72	111.50	120.57	116.03	136.53	138.88	137.71	140.97	154.50	47.73	150.37	165.93	158.15	158.13	177.47	167.80
F+VC+AZOS)	27.86	26.45	27.15	54.13	56.75	53.44	110.57	117.95	114.26	132.59	136.65	134.62	136.27	151.39	43.83	147.63	162.97	155.30	156.16	172.90	164.53
F+VC+AZOS)	25.35	25.14	25.25	50.13	52.68	53.41	100.40	110.30	105.35	126.42	132.24	129.33	130.13	142.33	36.23	142.10	155.73	148.92	148.67	160.60	154.63
3M)	22.03	22.32	22.18	41.40	46.80	44.10	88.00	92.35	90.17	100.60	125.20	117.90	120.20	142.40	31.30	136.93	147.17	142.05	143.12	153.87	148.49
3M+AZOS)	22.15	23.39	22.77	42.00	54.24	48.12	93.60	96.34	94.97	122.01	135.47	128.74	124.97	150.89	37.93	140.47	156.14	148.31	147.10	161.00	154.05
F+GM+AZOS)	21.00	22.00	21.50	40.60	50.53	45.57	89.71	95.12	92.42	109.05	132.44	125.75	122.13	148.13	35.13	135.27	154.37	144.82	145.21	158.40	151.81
F+GM+AZOS)	21.23	21.37	21.30	39.40	44.47	41.94	86.60	90.05	88.32	103.20	123.70	118.45	120.90	138.73	29.82	134.30	145.22	139.76	140.03	150.43	145.23
Mean	24.37	24.53		47.13	51.38		99.44	103.39		124.44	130.17		129.50	###		141.01	153.81		148.27	160.72	
	1.08	1.18		1.22	2.13		2.32	2.08		1.58	1.84		1.60	1.93		1.21	1.67		1.83	2.27	
	NS	NS		3.57	6.23		6.76	6.07		4.60	5.37		4.68	5.64		3.53	4.88		5.33	6.63	

During 2002-03, significantly greater plant height was recorded by T7 treatment (111.50 cm) at 90 DAP, compared to other treatments, while T13 (86.60 cm), T1 (90.67 cm), T10 (88.00 cm) and T12 (89.71 cm) treatments had recorded lowest plant height. During 2003-04 also, T7 treatment had recorded highest plant height (120.57 cm) and the treatment, T8 (117.95 cm) was observed to be statistically on a par with T7 treatment. Lowest plant height was recorded by T13 treatment (90.05 cm) during the year. Further, T1 (90.27 cm), T10 (92.35 cm) and T12 (95.12 cm) treatments had recorded plant height statistically on a par with T1 treatment during 2003-04.

At 120 days after planting, T7 treatment had recorded highest plant height during both 2002-03 (136.53 cm) and 2003-04 (138.88 cm). Further, T8 treatment (132.59 cm) during 2002-03; and T6 (134.79 cm), T8 (136.65 cm) and T11 (135.47 cm) treatments during 2003-04 had recorded plant height on a par with T7 treatment. In contrast, T1 treatment had recorded lowest plant height during both 2002-03 (110.53 cm) and 2003-04 (120.63 cm).

At 150 DAP also, T7 had recorded highest plant height during both 2002-03 (140.97 cm) and 2003-04 (154.50 cm). The treatments, T8 (151.39 cm) and T11 (150.89 cm) during 2003-04 had recorded plant height on a par with T7 treatment. Further, lowest plant height was recorded by T10 (120.20 cm) during 2002-03; and T1 treatment (133.03 cm) during 2003-04.

At 180 DAP, significantly greater plant height was recorded by T7 treatment (150.37 cm) during 2002-03, and was observed to be on a par with T8 treatment (147.63 cm), while lowest plant height was recorded by T1 treatment (132.40 cm).

During 2003-04 also, T7 treatment had recorded highest plant height (165.93 cm) and was observed to be on a par with T6 (161.47 cm) and T8 (162.97 cm) treatments. Further, T1 treatment had recorded lowest plant height (143.72 cm) during 2003-04.

At 210 DAP, highest plant height was recorded by T7 treatment (158.13 and 177.47 cm), while lowest plant height was recorded for T1 treatment (136.03 and 146.20 cm) during both 2002-03 and 2003-04, respectively. Further, the treatments, T6 (154.27 and 170.83 cm, respectively) and T8 (156.16 and 172.90 cm, respectively) had recorded plant height on a par with T7 treatment during 2002-03 and 2003-04.

4.2.2 Stem girth

The results are presented in Table 19. An increase in stem girth from 2.64 cm to 8.55 cm during 2002-03; and from 2.78 cm to 8.74 cm during 2003-04 was observed in the present investigation with an increase in the crop age from 30 to 210 DAP. Further, greater stem girth was in general noticed during 2003-04, compared to 2002-03 at 30, 60, 150, 180 and 210 DAP.

The application of farm yard manure, vermicompost, green manure and bio-fertilizer, *Azospirillum* in combination with different doses of recommended NPK inorganic fertilizers was resulted in non-significant effect on stem girth at 30 DAP, 60 DAP and 90 DAP during both 2002-03 and 2003-04. However, significant differences were noticed among the treatments for stem girth at 120, 150 180 and 210 DAP during both the years of investigation.

Table 19 : Stem girth (cm) as influenced by integrated nutrient management in cassava under irrigated conditions

Treatments	30 DAP		60 DAP		90 DAP		120 DAP		150 DAP		180 DAP		210 DAP								
	Mean	02-03 03-04	Mean	02-03 03-04	Mean	02-03 03-04	Mean	02-03 03-04	Mean	02-03 03-04	Mean	02-03 03-04	Mean	02-03 03-04							
T ₁ (RDF)	2.66	2.77	2.71	3.70	4.30	4.00	6.73	5.63	6.18	6.83	6.37	6.60	7.87	7.70	7.78	8.10	8.07	8.08	8.12	8.13	8.13
T ₂ (RDF+FYM)	2.90	2.83	2.87	4.13	5.05	4.59	7.27	6.03	6.65	7.60	7.00	7.30	8.00	8.17	3.08	8.23	8.30	8.27	8.50	8.37	8.43
T ₃ (RDF+FYM+AZOS)	2.60	2.97	2.78	4.50	5.40	4.95	7.67	6.57	7.12	7.70	7.63	7.67	8.17	8.73	3.45	8.63	8.87	8.75	8.67	8.93	8.80
T ₄ (1/3 RDF+FYM+AZOS)	2.89	2.90	2.90	4.23	5.20	4.72	7.23	6.43	6.83	7.63	7.30	7.47	8.37	8.60	3.48	8.40	8.73	8.57	8.47	8.87	8.67
T ₅ (1/2 RDF+FYM+AZOS)	2.92	2.74	2.83	4.03	5.13	4.58	6.97	6.40	6.69	7.13	6.90	7.02	8.10	8.00	3.05	8.13	8.30	8.22	8.43	8.53	8.48
T ₆ (RDF+VC)	2.91	3.01	2.96	4.60	5.30	4.95	7.27	6.50	6.88	7.97	7.90	7.93	8.43	8.73	3.58	8.63	8.83	8.73	8.78	9.00	8.89
T ₇ (RDF+VC+AZOS)	3.04	3.20	3.12	4.70	5.80	5.25	7.70	7.30	7.50	8.10	8.17	8.13	8.77	9.00	3.89	8.80	9.12	8.96	8.85	9.23	9.04
T ₈ (1/3 RDF+VC+AZOS)	2.98	3.01	2.99	4.60	5.47	5.03	7.23	6.83	7.03	8.07	8.00	8.03	8.70	8.87	3.78	8.70	9.00	8.85	8.73	9.07	8.90
T ₉ (1/2 RDF+VC+AZOS)	2.83	2.93	2.88	4.30	5.10	4.70	7.30	6.23	6.77	8.00	7.77	7.88	8.27	8.50	3.38	8.40	8.63	8.52	8.41	8.83	8.62
T ₁₀ (RDF+GM)	2.15	2.37	2.26	3.60	4.14	3.87	6.70	5.40	6.05	7.03	6.77	6.90	8.03	8.13	3.08	8.37	8.27	8.32	8.47	8.50	8.48
T ₁₁ (RDF+GM+AZOS)	2.21	2.60	2.41	3.13	4.37	3.75	7.10	5.60	6.35	7.13	7.00	7.07	8.13	8.57	3.35	8.57	8.72	8.64	8.67	8.87	8.77
T ₁₂ (1/3 RDF+GM+AZOS)	2.11	2.57	2.34	3.17	4.30	3.73	7.23	5.50	6.37	7.07	6.97	7.02	8.27	8.50	3.38	8.55	8.60	8.58	8.63	8.73	8.68
T ₁₃ (1/2 RDF+GM+AZOS)	2.17	2.23	2.20	3.13	4.13	3.63	6.77	5.30	6.03	6.90	6.60	6.75	8.07	7.97	3.02	8.37	8.20	8.28	8.45	8.50	8.47
General Mean	2.64	2.78		3.99	4.90		7.17	6.13		7.47	7.26		8.24	8.42		8.45	8.59		8.55	8.74	
S.E.m	0.12	0.13		0.24	0.21		0.45	0.25		0.22	0.24		0.22	0.18		0.15	0.17		0.19	0.13	
C.D (0.05)	NS	NS		NS	NS		NS	NS		0.63	0.69		0.63	0.54		0.44	0.50		0.55	0.38	

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At 120 DAP, highest stem girth was recorded by T7 treatment, (8.10 cm and 8.17 cm) while lowest was recorded by T1 treatment (6.83 cm and 6.37 cm) during both 2002-03 and 2003-04, respectively. Further, the treatments T2 (7.60 cm), T3 (7.70 cm), T4 (7.63 cm), T6 (7.97 cm), T8 (8.07 cm) and T9 (8.00 cm) during 2002-03; T3 (7.63 cm), T6 (7.90 cm), T8 (8.00 cm) and T9 (7.77 cm) during 2003-04 had recorded stem girth on a par with T7 treatment.

Highest stem girth at 150 DAP was recorded by T7 treatment (8.77 cm and 9.00 cm), while lowest was recorded by T1 treatment (7.87 cm and 7.70 cm) during both 2002-03 and 2003-04, respectively. Further, the treatments T3 (8.17 cm), T4 (8.37 cm), T6 (8.43 cm), T8 (8.70 cm), T9 (8.27 cm) and T12 (8.27 cm) during 2002-03; and T3 (8.73 cm), T4 (8.60 cm), T6 (8.73 cm), T8 (8.87 cm), T9 (8.50 cm), T11 (8.57 cm) and T12 (8.50 cm) during 2003-04 had recorded stem girth on a par with T7 treatment.

At 180 DAP, highest stem girth was recorded by T7 (8.80 cm) treatment and was observed to be statistically on a par with the stem girth recorded by T3 (8.63 cm), T4 (8.40 cm), T6 (8.63 cm), T8 (8.70 cm), T9 (8.40 cm), T10 (8.37 cm), T11 (8.57 cm), T12 (8.55 cm) and T13 (8.37 cm) treatments, while lowest stem girth was recorded by T1 (8.10 cm) treatment during 2002-03. Further, the treatment T7 (9.12 cm) has also recorded highest stem girth during 2003-04 and was observed to be statistically on a par with the stem girth recorded by T3 (8.87 cm), T4 (8.73 cm), T6 (8.83 cm), T8 (9.00 cm), T9 (8.63 cm) and T11 (8.72 cm) treatments.

Highest stem girth at 210 DAP was also recorded by T7 treatment during both 2002-03 (8.85 cm) and 2003-04 (9.23 cm). Further, it was observed to be on a

par with the stem girth recorded by T2 (8.50 cm), T3 (8.67 cm), T4 (8.47 cm), T5 (8.43 cm), T6 (8.78 cm), T8 (8.73 cm), T9 (8.41 cm), T10 (8.47 cm), T11 (8.67 cm), T12 (8.63 cm) and T13 (8.45 cm) treatments during 2002-03; and T3 (8.93 cm), T4 (8.87 cm), T6 (9.00 cm), T8 (9.07 cm) and T11 (8.87 cm) treatments during 2003-04. Lowest stem girth was however recorded by T1 treatment during 2002-03 (8.12 cm) and 2003-04 (8.13 cm).

4.2.3 Number of nodes

The results are presented in Table 20. Number of nodes was noticed to increase from 24.42 to 160.96 during 2002-03 and from 28.23 to 168.63 during 2003-04 with an increase in the crop age from 30 to 210 DAP. Further, greater number of nodes per plant was in general observed during 2003-04, compared to 2002-03 at the different growth stages studied, except at 60 and 120 DAP.

The INM treatments imposed in the present investigation did not exhibit any significant influence on the number of nodes per plant at 30 DAP during 2002-03 and 2003-04. However, significant difference were observed among the treatments at 60, 90, 120, 150, 180 and 210 DAP, during both the years of investigation.

At 60 DAP; highest number of nodes per plant was recorded by T7 treatment (61.97 and 62.87), while lowest was recorded by T13 treatment (42.13 and 41.60) during 2002-03 and 2003-04, respectively. Further, the treatments, T3 (60.40), T4 (61.13), T6 (58.47) and T8 (59.57) during 2002-03; and T8 (60.00) during 2003-04 were observed to be on a par with T7 treatment.

At 90 DAP, the highest number of nodes per plant was recorded by T7 treatment (118.53), while lowest number was recorded by T13 treatment (94.67)

Table 20 : Number of nodes per plant as influenced by integrated nutrient management in cassava under irrigated conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	DF)	23.47	26.00	24.73	49.33	48.57	48.95	97.60	102.48	100.04	131.20	128.47	129.83	132.27	143.07	137.67	140.00	149.90	144.95	148.41	152.40
DF+FYM)	24.27	28.50	26.38	55.73	54.70	55.22	108.00	107.59	107.79	140.07	138.43	139.25	142.67	155.57	149.12	156.00	164.57	160.28	162.33	167.40	164.97
DF+FYM+AZOS)	24.87	30.42	27.64	60.40	58.53	59.47	118.13	116.41	117.27	146.63	141.27	143.95	160.00	164.50	164.25	162.53	172.67	167.60	166.27	174.67	170.47
1/3 RDF+FYM+AZOS)	24.73	29.02	26.88	61.13	57.17	59.15	109.67	113.87	111.77	142.03	140.53	141.28	153.67	163.40	159.04	154.10	167.03	160.57	160.96	170.53	165.30
1/2 RDF+FYM+AZOS)	25.27	26.38	25.82	53.67	54.16	53.91	110.07	105.89	107.98	136.67	134.06	135.36	145.53	153.93	149.28	151.60	160.07	155.83	157.97	164.93	161.45
DF+VC)	26.40	30.45	28.43	58.47	58.80	58.63	111.87	116.91	114.39	150.13	142.55	146.34	160.27	160.00	160.13	161.47	169.63	170.05	163.20	172.50	167.85
DF+VC+AZOS)	28.13	32.07	30.10	61.97	62.87	61.22	118.53	125.12	121.83	160.57	147.27	153.92	168.47	168.37	168.42	179.33	175.27	177.30	180.20	182.37	181.28
1/3 RDF+VC+AZOS)	26.47	31.40	28.93	59.57	60.00	60.98	105.87	120.72	113.30	155.96	145.42	150.69	164.93	166.50	166.72	165.40	172.43	168.92	168.49	176.40	172.45
1/2 RDF+VC+AZOS)	25.53	29.50	27.52	56.60	56.55	56.57	104.93	112.83	108.88	144.30	138.80	141.55	158.47	158.89	160.66	160.00	165.63	162.82	160.40	168.27	164.33
RDF+GM)	22.47	25.49	23.98	45.00	43.77	44.38	101.80	88.47	95.13	134.40	133.07	133.73	135.70	153.77	144.73	145.93	157.80	152.37	154.72	162.57	158.64
RDF+GM+AZOS)	22.80	27.32	25.06	46.67	46.13	46.40	100.83	94.00	97.42	140.05	140.10	140.08	140.27	158.16	149.21	152.40	166.90	159.65	163.55	171.10	167.33
1/3 RDF+GM+AZOS)	21.30	26.12	23.71	42.27	45.25	43.76	99.67	92.01	95.84	135.15	134.00	134.57	138.67	157.16	147.92	146.87	165.37	156.12	155.33	168.60	161.96
1/2 RDF+GM+AZOS)	21.80	24.37	23.08	42.13	41.60	41.87	94.67	88.00	91.33	133.20	131.87	132.53	135.00	149.47	142.23	144.03	156.03	150.03	151.32	160.43	155.88
Grand Mean	24.42	28.23		53.30	52.93		106.28	106.48		142.34	138.14		148.92	157.84		155.44	164.87		160.95	168.63	
0.05)	1.75	1.10		1.61	1.15		2.39	2.36		2.15	1.56		2.87	2.55		1.80	2.41		1.65	2.42	
	NS	NS		4.69	3.35		6.96	6.88		6.27	4.56		8.37	6.39		5.25	7.03		4.82	7.07	

during 2002-03. However, T3 (118.13) and T6 (111.87) treatments were found to be on a par with T7 treatment. During 2003-04 also, T7 treatment had recorded highest number of nodes per plant (125.12) and was found to be on a par with T8 (120.72), while lowest number of nodes was recorded by T13 treatment (88.00) during the year.

At 120 DAP, highest number of nodes per plant were recorded by T7 treatment (160.57 and 147.27), while lowest number was recorded by T1 treatment (131.20 and 128.47) during 2002-03 and 2003-04, respectively. Further, the treatment T8 (155.96 and 145.42, respectively) was found to be on a par with T7 treatment during 2002-03 and 2003-04.

At 150 DAP, highest number of nodes per plant was recorded by T7 treatment for both 2002-03 (168.47) and 2003-04 (168.37), while lowest was recorded by T1 treatment (132.27 and 143.07, respectively) during 2002-03 and 2003-04. Further, the treatments T6 (160.27) and T8 (164.93) during 2002-03; and T3 (164.50), T4 (163.40) and T8 (166.50) were found to be statistically on a par with T7 treatment during 2003-04.

Highest number of nodes per plant was recorded by T7 treatment at 180 (179.33 and 175.27, respectively) and 210 (180.20 and 182.37, respectively) DAP for both 2002-03 and 2003-04 years of investigation, while lowest number of nodes was recorded by T1 treatment at 180 (140.00 and 149.90, respectively) and 210 (148.41 and 152.40, respectively) DAP for both 2002-03 and 2003-04. Further, the treatments T3 (172.67), T6 (169.63) and T8 (172.43) at 180 DAP during 2003-04;

T8 (176.40) at 210 DAP during 2003-04 were found to be on a par with T7 treatment.

4.2.4 Number of leaves

Results on the effect of INM treatments on number of leaves per plant at different growth stages are presented in Table 21. The leaf number was observed to increase from 23.58 to 141.70 during 2002-03 and from 23.94 to 152.88 during 2003-04 with an increase in the crop age from 30 to 150 DAP. However, decrease in the leaf number was observed from 114.42 to 104.31 during 2002-03, and from 126.01 to 103.25 during 2003-04 with an increase in the crop age from 180 to 210 DAP. Further, greater number of leaves per plant were in general noticed during 2003-04, compared to 2002-03 at all the growth stages studied, except at 210 DAP.

The INM treatments studied in the present investigation were observed to be non-significant with regards to their influence on number of leaves per plant at 30 DAP during 2002-03 and 2003-04. However, a significant influence of the treatments was observed at all other growth stages studied.

At 60 DAP, T7 treatment had recorded highest number of leaves per plant during 2002-03 (54.77) and 2003-04 (56.36). The treatments, T3 (51.47), T4 (52.07), T6 (50.60) and T8 (54.41) during 2002-03 had also recorded number of leaves per plant on a par with T7 treatment. However, T13 during 2002-03 (34.33) and 2003-04 (38.95) had recorded lowest number of leaves per plant.

At 90 DAP, T7 treatment had recorded highest number of leaves per plant during 2002-03 (112.62) and 2003-04 (113.12). The treatment, T8 during 2002-03 (110.19) and 2003-04 (109.85) had also recorded number of leaves per plant on a

Table 21 : Number of leaves per plant as influenced by integrated nutrient management in cassava under irrigated conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	(F)	22.17	22.70	22.44	40.27	42.70	41.48	86.30	94.37	90.33	123.40	125.70	124.55	128.87	136.36	132.62	100.20	112.40	106.30	93.17	89.57
(F+FYM)	23.07	24.50	23.78	45.20	43.20	44.20	96.53	101.07	98.80	130.37	132.60	131.48	140.36	152.80	146.58	116.67	122.57	119.62	100.20	98.60	99.40
(F+FYM+AZOS)	23.20	26.27	24.73	51.47	48.20	49.83	99.67	106.00	102.83	136.85	138.00	137.42	148.45	160.38	154.42	120.73	132.42	126.58	104.70	110.67	107.68
1 RDF+FYM+AZOS)	24.27	25.60	24.93	52.07	46.28	49.17	96.37	103.33	99.85	129.15	135.00	132.08	150.28	156.20	153.24	120.53	123.03	121.78	109.60	104.13	106.87
2 RDF+FYM+AZOS)	22.44	23.80	23.12	40.13	41.88	41.01	95.95	100.67	98.31	126.67	130.40	128.53	136.18	148.88	142.53	110.27	118.03	114.15	106.07	97.30	101.68
(F+VC)	24.93	25.81	25.37	50.60	52.12	51.36	104.96	105.77	105.37	134.20	136.20	135.20	146.29	156.52	151.41	122.83	127.23	125.03	110.73	107.56	109.15
(F+VC+AZOS)	28.33	26.92	27.63	54.77	56.36	55.57	112.62	113.12	112.87	140.10	142.87	141.48	155.61	164.53	160.07	124.40	137.37	130.88	118.13	116.63	117.38
3 RDF+VC+AZOS)	26.13	26.00	26.07	54.41	50.32	52.37	110.19	109.85	110.02	134.20	138.50	136.35	153.93	162.75	158.34	120.60	135.64	128.12	108.40	112.13	110.27
2 RDF+VC+AZOS)	23.50	24.03	23.77	45.55	50.23	47.89	98.07	100.60	99.34	130.60	130.57	130.58	142.38	152.92	147.65	112.50	125.64	119.07	106.83	102.32	104.58
DF+GM)	21.71	21.67	21.69	36.60	40.07	38.33	76.27	88.43	82.35	126.05	126.37	126.21	130.92	145.47	138.20	109.73	122.17	115.95	98.73	97.17	97.95
DF+GM+AZOS)	23.41	22.17	22.79	38.84	43.60	41.22	82.73	93.57	88.15	128.83	134.16	131.50	140.16	154.57	147.41	114.63	130.23	122.43	102.73	106.00	104.37
3 RDF+GM+AZOS)	21.63	21.20	21.42	37.04	42.30	39.67	76.87	92.12	84.49	126.27	131.11	128.69	139.52	152.63	146.08	110.87	126.84	118.86	100.00	104.30	102.15
2 RDF+GM+AZOS)	21.80	20.60	21.20	34.33	38.95	36.64	76.00	88.06	82.03	123.60	123.29	123.45	129.16	143.30	136.23	103.43	124.51	113.97	96.67	95.93	96.30
Total Mean	23.58	23.94		44.71	45.86		93.27	99.77		130.02	132.67		141.70	152.85		114.42	126.01		104.31	103.25	
(.05)	1.11	0.92		1.88	0.86		2.45	2.11		1.19	1.50		4.13	2.21		1.30	1.96		2.11	2.98	
	NS	NS		5.48	2.52		7.15	6.17		3.48	4.36		12.05	8.10		3.79	5.71		6.17	8.69	

par with T7 treatment. Further, lowest leaves per plant were recorded for T13 treatment during 2002-03 (76.00) and 2003-04 (88.06).

The treatment, T7 has also recorded highest number of leaves per plant at 120 DAP during both 2002-03 (140.10) and 2003-04 (142.87). Further, the treatments, T3 (136.85) during 2002-03 and T8 (138.50) during 2003-04 were observed to be on a par with T7 treatment. Lowest number of leaves per plant was recorded by the treatment T1 (123.40) during 2002-03 and T13 (123.29) during 2003-04.

At 150 DAP also, T7 treatment had recorded highest number of leaves per plant during 2002-03 (155.61) and 2003-04 (164.53). The treatments, T3 (148.45), T4 (150.28), T6 (146.29) and T8 (153.93) during 2002-03; and T3 (160.38), T6 (156.52) and T8 (162.75) during 2003-04 had also recorded number of leaves per plant on a par with T7 treatment. Further, lowest number of leaves per plant was recorded by T1 treatment during both 2002-03 (128.87) and 2003-04 (136.36).

T7 treatment had also recorded highest number of leaves per plant at 180 DAP during 2002-03 (124.40) and 2003-04 (137.37). Further, the treatments, T3 (120.73) and T6 (122.83) during 2002-03; T3 (132.42) and T8 (135.64) during 2003-04 had recorded number of leaves per plant on a par with T7 treatment. Lowest number of leaves per plant was recorded was recorded by T1 treatment during both 2002-03 (100.20) and 2003-04 (112.40).

At 210 DAP, T7 treatment had recorded highest number of leaves per plant during 2002-03 (118.13) and 2003-04 (116.63). Further, T3 (110.67) and T8 (112.13) treatment had recorded number of leaves on a par with T7 treatment during

2003-04. Lowest number of leaves per plant was recorded with T1 treatment during both 2002-03 (93.17) and 2003-04 (89.57).

4.2.5 Leaf area

The results are presented in Table 22. An increase in leaf area/plant with increase in the crop age was observed up to 150 days after planting during both years of investigation. However, at later growth stages, leaf area decreased with an increase in the crop age. The application of INM treatments was also observed to exert a significant influence on the leaf area per plant at all the growth stages studied.

Among the treatments, T7 had consistently recorded highest leaf area at all the growth stages during 2002-03 (2008 cm² at 30 DAP, 4711 cm² at 60 DAP, 22601 cm² at 90 DAP, 25000 cm² at 120 DAP, 35855 cm² at 150 DAP, 27994 cm² at 180 DAP and 19547 cm² at 210 DAP) and 2003-04 (1737 cm² at 30 DAP, 4860 cm² at 60 DAP, 20857 cm² at 90 DAP, 26904 cm² at 120 DAP, 29683 cm² at 150 DAP, 25820 cm² at 180 DAP and 18535 cm² at 210 DAP). The treatments, T8 (1917 cm²) at 30 DAP; T3 (4495 cm²), T4 (4494 cm²), T6 (4626 cm²) and T8 (4696 cm²) at 60 DAP; T8 (22013 cm²) at 90 DAP; T3 (24747 cm²), T4 (23702 cm²), T6 (23437 cm²) and T8 (23983 cm²) at 120 DAP; T8 (34148 cm²) at 150 DAP; T3 (26730 cm²) and T6 (25782 cm²) at 180 DAP; and T4 (18673 cm²), T6 (17937 cm²) and T8 (18508 cm²) at 210 DAP had recorded leaf area per plant on a par with T7 treatment during 2002-03; while T2 (1558 cm²), T3 (1679 cm²), T4 (1649 cm²), T6 (1674 cm²) and T8 (1728 cm²) at 30 DAP; T3 (28448 cm²), T6 (28208 cm²) and T8 (28689 cm²) at 150 DAP; T3 (23837 cm²) and T8 (23963 cm²)

22 : Leaf area per plant (cm²) as influenced by integrated nutrient management in cassava under irrigated conditions

Treatments	30 DAP				60 DAP				90 DAP				120 DAP				150 DAP				180 DAP				210 DAP																																																																																																																																																																																																																																																							
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean																																																																																																																																																																																																																																																					
	1238	1383	1310	3133	2791	2962	14243	13613	13928	20189	19191	19690	25446	23091	24268	18658	19073	18866	15227	12420	13824	1275	1558	1417	3747	3267	3507	18317	15728	17022	22673	21744	22209	27931	26603	27267	25105	21690	23398	16890	16152	16521	1386	1679	1532	4495	4076	4285	18407	17696	18051	24747	23478	24112	30655	28448	29552	26730	23837	25283	17683	17484	17583	1347	1649	1498	4494	3688	4091	18383	15997	17190	23702	22442	23072	28701	27201	27951	23625	21962	22793	18673	17361	18017	1274	1463	1369	4087	3333	3710	16966	15151	16059	21669	21311	21490	27694	25517	26606	21562	21023	21293	15888	14367	15128	1579	1674	1626	4626	4245	4436	17713	17663	17688	23437	22331	22884	32268	28208	30238	25782	22331	24056	17937	16620	17278	2008	1737	1873	4711	4860	4785	22601	20857	21729	25000	26904	25952	35855	29683	32769	27994	25820	26907	19547	18535	19041	1917	1728	1823	4696	4488	4592	22013	18830	20421	23983	23546	23765	34148	28689	31418	21237	23963	22600	18508	16528	17518	1662	1472	1567	3856	4306	4081	18553	16373	17463	21382	21187	21285	30449	25927	28188	19910	21208	20559	16889	13890	15389	1305	1299	1302	2682	2755	2719	14303	14045	14174	20661	20274	20467	27263	25320	26292	20304	20860	20582	16876	14784	15830	1342	1357	1349	2781	2925	2853	15224	14653	14938	21640	21333	21487	30071	27265	28668	22456	22712	22584	17079	16857	16968	1277	1302	1289	2707	2780	2743	14984	14245	14614	20708	20556	20632	28978	26054	27516	22254	21002	21628	16671	15304	15987	1213	1061	1137	2172	2433	2302	14131	13411	13771	19963	18970	19466	28165	24713	26439	18840	20015	19428	16380	13567

1448 1489 3707 3534 17372 16020 22289 21790 29817 26671 22651 21961 17250 15682

78 84 172 72 620 523 589 685 644 575 804 712 587 591

226 244 502 211 1809 1527 1719 1999 1880 1678 2346 2078 1714 1726

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at 180 DAP; and T3 (17484 cm²), T4 (17361 cm²) and T11 (16857 cm²) at 210 DAP had recorded leaf area on per with the best treatment (T7) during 2003-04. However, lowest leaf area was recorded by T13 treatment at 30, 60, 90 and 120 DAP during 2002-03 (1213 cm², 2172 cm², 14131 cm² and 19963 cm², respectively) and 2003-04 (1061 cm², 2433 cm², 13411 cm² and 18970 cm², respectively), while T1 treatment had recorded lowest leaf area per plant at 150, 180 and 210 DAP during 2002-03 (25446 cm², 18658 cm² and 15227 cm², respectively) and 2003-04 (23091 cm², 19073 cm² and 12420 cm², respectively).

4.2.6 Leaf area index

The experimental results are presented in Table 23. An increase in leaf area index was observed with an increase in the crop age up to 150 DAP. However, at later stages of the crop growth (180 and 210 DAP) a decrease in the leaf area index was noticed with increase in the crop age. Further, leaf area index was in general observed to be higher during 2002-03, compared to 2003-04 at different growth stages studied, with the exception of leaf area index at 30 DAP.

The application of various INM treatments to resulted in a significant influence on leaf area index per plant at all the crop growth stages studied. T7 treatment had recorded highest leaf area index at 30 (0.248), 60 (0.582), 90 (2.790), 120 (3.086), 150 (4.427), 180 (3.456) and 210 (2.413) DAP during 2002-03; and 30 (0.215), 60 (0.600), 90 (2.575), 120 (3.321), 150 (3.664), 180 (3.188) and 210 (2.288) DAP during 2003-04. Further, the treatments T8 (0.237) at 30 DAP; T3 (0.555), T4 (0.555), T6 (0.571) and T8 (0.580) at 60 DAP; T8 (2.718) at 90 DAP; T3 (3.055), T4 (2.926), T6 (2.893) and T8 (2.961) at 120 DAP; T8 (4.216) at 150

Table 23 : Leaf area index as influenced by integrated nutrient management in cassava under irrigated conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP			210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	DF)	0.153	0.171	0.162	0.387	0.345	0.366	1.758	1.681	1.720	2.492	2.369	2.431	3.141	2.851	2.996	2.303	2.355	2.329	1.860	1.533
DF+FYM)	0.157	0.192	0.175	0.463	0.403	0.433	2.261	1.942	2.102	2.799	2.684	2.742	3.448	3.284	3.366	3.100	2.678	2.889	2.085	1.994	2.040
DF+FYM+AZOS)	0.171	0.207	0.189	0.555	0.503	0.529	2.272	2.185	2.229	3.055	2.898	2.977	3.785	3.512	3.648	3.300	2.943	3.122	2.183	2.159	2.171
1/3 RDF+FYM+AZOS)	0.166	0.204	0.185	0.555	0.455	0.505	2.269	1.975	2.122	2.926	2.771	2.849	3.543	3.358	3.451	2.917	2.711	2.814	2.305	2.143	2.224
1/2 RDF+FYM+AZOS)	0.157	0.180	0.169	0.505	0.411	0.458	2.094	1.870	1.982	2.675	2.631	2.653	3.419	3.150	3.285	2.662	2.595	2.629	1.962	1.774	1.868
DF+VC)	0.195	0.207	0.201	0.571	0.524	0.548	2.187	2.181	2.184	2.893	2.757	2.825	3.984	3.882	3.733	3.183	2.757	2.970	2.214	2.052	2.133
DF+VC+AZOS)	0.248	0.215	0.231	0.582	0.600	0.591	2.790	2.575	2.683	3.086	3.321	3.204	4.427	3.664	4.046	3.456	3.188	3.322	2.413	2.288	2.351
1/3 RDF+VC+AZOS)	0.237	0.213	0.225	0.580	0.554	0.567	2.718	2.325	2.521	2.961	2.907	2.934	4.216	3.542	3.879	2.622	2.958	2.790	2.285	2.041	2.163
1/2 RDF+VC+AZOS)	0.205	0.182	0.193	0.476	0.532	0.504	2.290	2.021	2.156	2.640	2.616	2.628	3.759	3.201	3.480	2.458	2.618	2.538	2.085	1.715	1.900
RDF+GM)	0.161	0.160	0.161	0.331	0.340	0.336	1.766	1.734	1.750	2.551	2.503	2.527	3.366	3.126	3.246	2.507	2.575	2.541	2.084	1.825	1.954
RDF+GM+AZOS)	0.166	0.167	0.167	0.344	0.361	0.352	1.880	1.809	1.844	2.672	2.634	2.653	3.712	3.366	3.539	2.772	2.804	2.788	2.109	2.081	2.095
1/3 RDF+GM+AZOS)	0.157	0.161	0.159	0.334	0.343	0.339	1.850	1.759	1.804	2.556	2.538	2.547	3.578	3.217	3.397	2.748	2.593	2.670	2.053	1.889	1.974
1/2 RDF+GM+AZOS)	0.150	0.131	0.140	0.268	0.300	0.284	1.744	1.656	1.700	2.465	2.342	2.403	3.477	3.051	3.264	2.326	2.471	2.399	2.022	1.675	1.849
Overall Mean	0.179	0.184		0.458	0.436		2.145	1.978		2.752	2.690		3.681	3.293		2.796	2.711		2.130	1.936	
0.05)	0.010	0.010		0.021	0.009		0.077	0.065		0.073	0.132		0.129	0.071		0.099	0.088		0.072	0.073	
	0.028	0.030		0.062	0.026		0.223	0.189		0.212	0.385		0.376	0.207		0.290	0.256		0.212	0.213	

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DAP; T3 (3.300) and T6 (3.183) at 180 DAP; and T4 (2.305), T6 (2.214) and T8 (2.285) at 210 DAP during 2002-03; and T2 (0.192), T3 (0.207), T4 (0.204), T6 (0.207) and T8 (0.213) and T9 (0.182) at 30 DAP; T3 (3.512), T6 (3.482) and T8 (3.542) at 150 DAP; T3 (2.943) and T8 (2.958) at 180 DAP; and T3 (2.159), T4 (2.143) and T11 (2.081) at 210 DAP during 2003-04 had recorded leaf area index on a par with T7 treatment. However, lowest leaf area index was recorded by T13 treatment at 30 (0.150 and 0.131), 60 (0.268 and 0.300), 90 (1.744 and 1.656) and 120 (2.465 and 2.342) DAP during 2002-03 and 2003-04, respectively; while T1 treatment had recorded lowest leaf area index at 150 (3.141 and 2.851), 180 (2.303 and 2.355) and 210 (1.880 and 1.533) DAP during 2002-03 and 2003-04, respectively.

4.2.7 Total dry matter production

The results are presented in Table 24. An increase in total dry matter production was observed with an increase in the crop age. Further, total dry matter production was noticed to be higher during 2003-04, compared to 2002-03 at all the growth stages studied in the present investigation. The effect of different INM treatments was also observed to be significant at all the growth stages. Highest total dry matter production was recorded uniformly by T7 treatment at 30 (0.26 t/ha), 60 (0.99 t/ha), 90 (2.74 t/ha), 120 (5.76 t/ha), 150 (11.67 t/ha) and 180 (14.90 t/ha) DAP during 2002-03; and 30 (0.27 t/ha), 60 (1.05 t/ha), 90 (2.90 t/ha), 120 (6.10 t/ha), 150 (12.35 t/ha) and 180 (15.76 t/ha) DAP during 2003-04. T8 treatment had also recorded highest dry matter production at 30 DAP during 2002-03 (0.26 t/ha) and 2003-04 (0.27 t/ha); and at 90 DAP during 2002-03 (2.74 t/ha) and 2003-04

Table 24 : Total drymatter production (tonnes per hectare) of cassava at different growth stages as influenced by integrated nutrient management under irrigated conditions

Treatments	30 DAP			60 DAP			90 DAP			120 DAP			150 DAP			180 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	0.21	0.22	0.22	0.68	0.72	0.70	2.21	2.34	2.28	5.01	5.30	5.16	8.29	8.77	8.53	11.53	12.20
T ₂ (RDF+FYM)	0.23	0.24	0.23	0.83	0.88	0.86	2.62	2.78	2.70	5.32	5.63	5.48	10.09	10.68	10.39	13.47	14.25	13.86
T ₃ (RDF+FYM+AZOS)	0.25	0.26	0.25	0.97	1.02	0.99	2.69	2.85	2.77	5.51	5.83	5.67	10.86	11.49	11.18	14.25	15.08	14.67
T ₄ (1/3 RDF+FYM+AZOS)	0.24	0.26	0.25	0.97	1.02	0.99	2.70	2.85	2.78	5.52	5.84	5.68	10.96	11.59	11.28	14.51	15.35	14.93
T ₅ (1/2 RDF+FYM+AZOS)	0.22	0.24	0.23	0.82	0.87	0.85	2.61	2.76	2.69	5.25	5.56	5.41	9.92	10.50	10.21	13.35	14.13	13.74
T ₆ (RDF+VC)	0.25	0.26	0.25	0.96	1.02	0.99	2.68	2.84	2.76	5.56	5.88	5.72	10.85	11.48	11.17	14.25	15.07	14.66
T ₇ (RDF+VC+AZOS)	0.26	0.27	0.27	0.99	1.05	1.02	2.74	2.90	2.82	5.76	6.10	5.93	11.67	12.35	12.01	14.90	15.76	15.33
T ₈ (1/3 RDF+VC+AZOS)	0.26	0.27	0.26	0.98	1.04	1.01	2.74	2.90	2.82	5.72	6.05	5.89	11.44	12.10	11.77	14.69	15.55	15.12
T ₉ (1/2 RDF+VC+AZOS)	0.25	0.26	0.25	0.95	1.00	0.97	2.64	2.80	2.72	5.53	5.85	5.69	10.74	11.36	11.05	14.22	15.05	14.64
T ₁₀ (RDF+GM)	0.21	0.22	0.22	0.71	0.75	0.73	2.27	2.41	2.34	5.17	5.47	5.32	9.45	10.00	9.73	13.35	14.12	13.74
T ₁₁ (RDF+GM+AZOS)	0.22	0.23	0.23	0.74	0.78	0.76	2.33	2.47	2.40	5.21	5.51	5.36	9.95	10.53	10.24	13.99	14.80	14.40
T ₁₂ (1/3 RDF+GM+AZOS)	0.22	0.23	0.22	0.74	0.78	0.76	2.33	2.46	2.40	5.19	5.50	5.35	10.03	10.62	10.33	14.01	14.83	14.42
T ₁₃ (1/2 RDF+GM+AZOS)	0.21	0.22	0.22	0.69	0.73	0.71	2.25	2.38	2.32	5.14	5.43	5.29	9.53	10.08	9.81	13.21	13.98	13.60
General Mean	0.23	0.25		0.85	0.90		2.52	2.67		5.38	5.69		10.29	10.89		13.83	14.63	
S.E.m	0.01	0.01		0.03	0.04		0.08	0.11		0.13	0.16		0.35	0.38		0.49	0.50	
C.D (0.05)	0.02	0.03		0.09	0.10		0.24	0.32		0.38	0.45		1.01	1.11		1.42	1.46	

(2.90 t/ha). Further, T3 (0.25 t/ha), T4 (0.24 t/ha), T6 (0.25 t/ha) and T9 (0.25 t/ha) at 30 DAP; T3 (0.97 t/ha), T4 (0.97 t/ha), T6 (0.96 t/ha), T8 (0.98 t/ha) and T9 (0.95 t/ha) at 60 DAP; T2 (2.62 t/ha), T3 (2.69 t/ha), T4 (2.70 t/ha), T5 (2.61 t/ha), T6 (2.68 t/ha) and T9 (2.64 t/ha) at 90 DAP; T3 (5.51 t/ha), T4 (5.52 t/ha), T6 (5.56 t/ha), T8 (5.72 t/ha) and T9 (5.53 t/ha) at 120 DAP; T3 (10.86 t/ha), T4 (10.96 t/ha), T6 (10.85 t/ha), T8 (11.44 t/ha) and T9 (10.74 t/ha) at 150 DAP; and T3 (14.25 t/ha), T4 (14.51 t/ha), T6 (14.25 t/ha), T8 (14.69 t/ha), T9 (14.22 t/ha), T11 (13.99 t/ha) and T12 (14.01 t/ha) at 180 DAP during 2002-03; T2 (0.24 t/ha), T3 (0.26 t/ha), T4 (0.26 t/ha), T5 (0.24 t/ha), T6 (0.26 t/ha) and T9 (0.26 t/ha) at 30 DAP; T3 (1.02 t/ha), T4 (1.02 t/ha), T6 (1.02 t/ha), T8 (1.04 t/ha) and T9 (1.00 t/ha) at 60 DAP; T2 (2.78 t/ha), T3 (2.85 t/ha), T4 (2.85 t/ha), T5 (2.76 t/ha), T6 (2.84 t/ha) and T9 (2.80 t/ha) at 90 DAP; T3 (5.83 t/ha), T4 (5.84 t/ha), T6 (5.88 t/ha), T8 (6.05 t/ha) and T9 (5.85 t/ha) at 120 DAP; T3 (11.49 t/ha), T4 (11.59 t/ha), T6 (11.48 t/ha), T8 (12.10 t/ha) and T9 (11.36 t/ha) at 150 DAP; and T3 (15.08 t/ha), T4 (15.35 t/ha), T6 (15.07 t/ha), T8 (15.55 t/ha), T9 (15.05 t/ha), T11 (14.80 t/ha) and T12 (14.83 t/ha) at 180 DAP during 2003-04 had recorded total dry matter production on a par with T7 treatment. However, lowest dry matter production was recorded by T1 treatment at 30, 60, 90, 120, 150 and 180 DAP during 2002-03 (0.21 t/ha, 0.68 t/ha, 2.21 t/ha, 5.01 t/ha, 8.29 t/ha and 11.53 t/ha, respectively); and 2003-04 (0.22 t/ha, 0.72 t/ha, 2.34 t/ha, 5.30 t/ha, 8.77 t/ha and 12.20 t/ha, respectively). In addition, T10 (0.21 and 0.22 t/ha, respectively) and T13 (0.21 and 0.22 t/ha, respectively) had also recorded lowest dry matter production at 30 DAP during 2002-03 and 2003-04.

4.2.8 Dry matter partitioning at harvest

The results are presented in Table 25 and Fig.11.

4.2.8.1 *Stem dry matter*

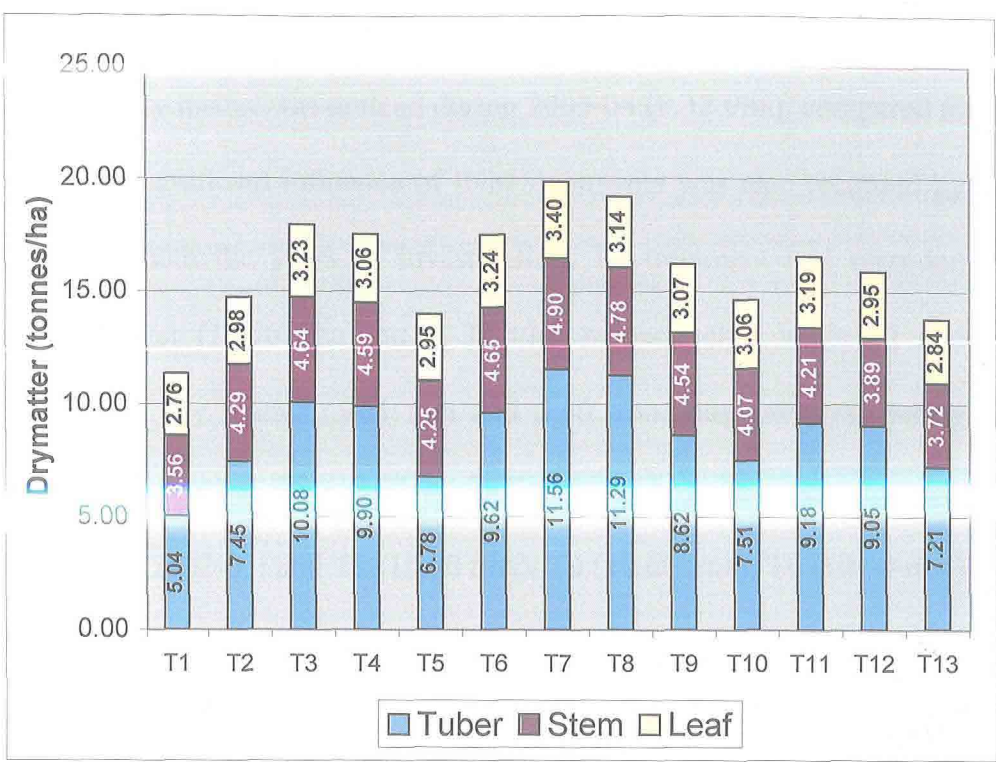
The stem dry matter was in general observed to be higher during 2003-04 (4.80 t/ha), compared to 2002-03 (4.31 t/ha). Significant influence of the INM treatments studied in the present investigation was also observed during both the years of investigation. T7 treatment had recorded highest stem dry matter (4.90 t/ha and 5.20 t/ha, respectively), while T1 treatment had recorded lowest stem dry matter (3.56 t/ha and 4.46 t/ha, respectively), during 2002-03 and 2003-04. The treatments, T3 (4.64 t/ha), T4 (4.59 t/ha), T6 (4.65 t/ha), T8 (4.78 t/ha) and T9 (4.54 t/ha) during 2002-03; and T3 (5.07 t/ha) T6 (5.18 t/ha), T8 (5.04 t/ha), T9 (5.01 t/ha) and T11 (4.79 t/ha) during 2003-04 had recorded stem dry matter on a par with T7 treatment.

4.2.8.2 *Leaf dry matter*

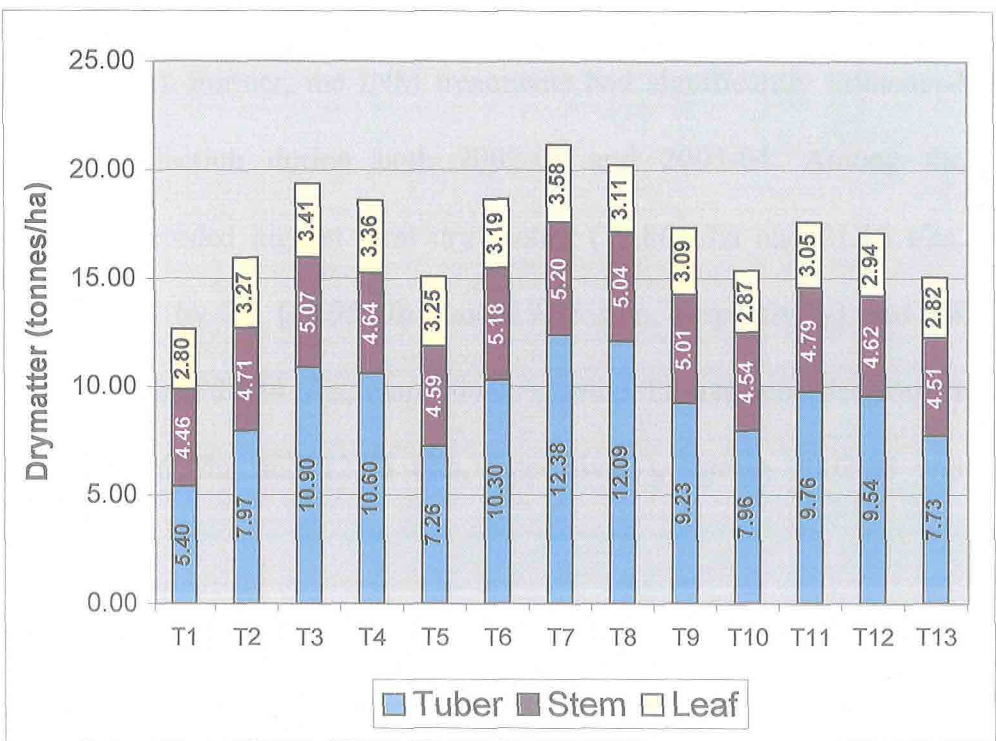
Leaf dry matter was noticed to be higher during 2003-04 (3.13 t/ha), compared to 2002-03 (3.07 t/ha). The different INM treatments studied in the present investigation exerted a significant influence on the leaf dry matter. The T7 treatment had recorded highest leaf dry matter (3.40 t/ha and 3.58 t/ha, respectively), while T1 treatment had recorded lowest leaf dry matter (2.76 t/ha and 2.80 t/ha, respectively), during 2002-03 and 2003-04. The treatments, T3 (3.23 t/ha), T6 (3.24 t/ha) and T11 (3.19 t/ha) during 2002-03; and T3 (3.41 t/ha) and T4 (3.36 t/ha) during 2003-04 had also recorded leaf dry matter on a par with T7 treatment.

Table 25 : Stem, leaf, tuber and total drymatter production (tonnes per hectare) of cassava at harvest (210 DAP) as influenced by integrated nutrient management under irrigated conditions

Treatments	Stem drymatter			Leaf drymatter			Tuber drymatter			Total drymatter		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	3.56	4.46	4.01	2.76	2.80	2.78	5.04	5.40	5.22	11.36	12.66	12.01
T ₂ (RDF+FYM)	4.29	4.71	4.50	2.98	3.27	3.13	7.45	7.97	7.71	14.72	15.95	15.34
T ₃ (RDF+FYM+AZOS)	4.64	5.07	4.86	3.23	3.41	3.32	10.08	10.90	10.49	17.95	19.38	18.67
T ₄ (1/3 RDF+FYM+AZOS)	4.59	4.64	4.62	3.06	3.36	3.21	9.90	10.60	10.25	17.55	18.60	18.08
T ₅ (1/2 RDF+FYM+AZOS)	4.25	4.59	4.42	2.95	3.25	3.10	6.78	7.26	7.02	13.98	15.10	14.54
T ₆ (RDF+VC)	4.65	5.18	4.92	3.24	3.19	3.22	9.62	10.30	9.96	17.51	18.67	18.09
T ₇ (RDF+VC+AZOS)	4.90	5.20	5.05	3.40	3.58	3.49	11.56	12.38	11.97	19.86	21.16	20.51
T ₈ (1/3 RDF+VC+AZOS)	4.78	5.04	4.91	3.14	3.11	3.13	11.29	12.09	11.69	19.21	20.24	19.73
T ₉ (1/2 RDF+VC+AZOS)	4.54	5.01	4.78	3.07	3.09	3.08	8.62	9.23	8.93	16.23	17.33	16.78
T ₁₀ (RDF+GM)	4.07	4.54	4.31	3.06	2.87	2.97	7.51	7.96	7.74	14.64	15.37	15.01
T ₁₁ (RDF+GM+AZOS)	4.21	4.79	4.50	3.19	3.05	3.12	9.18	9.76	9.47	16.58	17.60	17.09
T ₁₂ (1/3 RDF+GM+AZOS)	3.89	4.62	4.26	2.95	2.94	2.95	9.05	9.54	9.30	15.89	17.10	16.50
T ₁₃ (1/2 RDF+GM+AZOS)	3.72	4.51	4.12	2.84	2.82	2.83	7.21	7.73	7.47	13.77	15.06	14.42
General Mean	4.31	4.80		3.07	3.13		8.71	9.32		16.10	17.25	
S.Em	0.17	0.14		0.08	0.10		0.76	0.73		0.70	0.67	
C.D (0.05)	0.50	0.41		0.24	0.29		2.21	2.14		2.05	1.96	



2002-03



2003-04

Fig.11. Drymatter partitioning in cassava at harvest as influenced by integrated nutrient management under irrigated conditions

4.2.8.3 Tuber dry matter

Greater tuber dry matter was noticed during 2003-04 (9.32 t/ha), compared to 2002-03 (8.71 t/ha). Significant influence of INM treatments was also recorded by the character during both the years of investigation. T7 treatment had recorded highest tuber dry matter (11.56 t/ha and 12.38 t/ha, respectively), while T1 had recorded lowest tuber dry matter (5.04 t/ha and 5.40 t/ha, respectively), during 2002-03 and 2003-04. Further, T3 (10.08 t/ha), T4 (9.90 t/ha), T6 (9.62 t/ha) and T8 (11.29 t/ha) during 2002-03; and T3 (10.90 t/ha), T4 (10.60 t/ha), T6 (10.30 t/ha) and T8 (12.09 t/ha) during 2003-04 had recorded tuber dry matter on a par with T7 treatment.

4.2.8.4 Total dry matter

Higher total dry matter was recorded during 2003-04 (17.25 t/ha), compared to 2002-03 (16.10 t/ha). Further, the INM treatments had significantly influenced total dry matter production during both 2002-03 and 2003-04. Among the treatments, T7 had recorded highest total dry matter (19.86 t/ha and 21.16 t/ha, respectively), followed by T3 (17.95 t/ha and 19.38 t/ha, respectively) and T8 treatments (19.21 t/ha and 20.24 t/ha, respectively), while T1 had recorded lowest total dry matter (11.36 t/ha and 12.66 t/ha, respectively), during 2002-03 and 2003-04.

4.2.9 Crop growth rate (CGR)

The results are presented in Table 26. An increase in the crop growth rate was noticed in the present investigation with an increase in the crop age upto 150 DAP. However, at later stages, the CGR decreased with increasing crop age.

Table 26 : Crop growth rate ($\text{g m}^{-2} \text{ day}^{-1}$) at different growth stages in cassava as influenced by integrated nutrient management under irrigated conditions

Treatments	30-60 DAP			60-90 DAP			90-120 DAP			120-150 DAP			150-180 DAP			180-210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	1.56	1.65	1.61	5.10	5.39	5.25	8.82	9.33	9.08	10.91	11.55	11.23	10.82	11.45	11.14	3.18	3.36	3.27
T ₂ (RDF+FYM)	2.03	2.15	2.09	5.96	6.31	6.14	9.87	10.32	10.10	16.91	16.83	16.87	11.26	11.91	11.59	5.66	5.99	5.83
T ₃ (RDF+FYM+AZOS)	2.40	2.54	2.47	5.74	6.08	5.91	9.92	10.46	10.19	18.12	18.86	18.49	11.29	11.95	11.62	10.86	11.49	11.18
T ₄ (1/3 RDF+FYM+AZOS)	2.42	2.56	2.49	5.76	6.10	5.93	9.67	10.25	9.96	17.83	19.18	18.51	11.83	12.52	12.18	10.76	11.39	11.08
T ₅ (1/2 RDF+FYM+AZOS)	2.00	2.11	2.06	5.96	6.30	6.13	9.56	10.13	9.85	16.57	16.48	16.53	11.44	12.10	11.77	3.80	4.02	3.91
T ₆ (RDF+VC)	2.38	2.52	2.45	5.75	6.09	5.92	9.57	10.52	10.05	19.65	18.68	19.17	11.32	11.97	11.65	10.07	10.65	10.36
T ₇ (RDF+VC+AZOS)	2.46	2.60	2.53	5.83	6.17	6.00	10.07	10.66	10.37	19.83	20.98	20.41	10.85	11.48	11.17	13.26	14.04	13.65
T ₈ (1/3 RDF+VC+AZOS)	2.42	2.57	2.50	5.84	6.18	6.01	9.94	10.34	10.14	19.21	20.01	19.61	10.76	11.39	11.08	13.35	14.13	13.74
T ₉ (1/2 RDF+VC+AZOS)	2.35	2.48	2.42	5.64	5.97	5.81	9.64	10.20	9.92	19.06	18.37	18.72	11.61	12.28	11.95	7.05	7.46	7.26
T ₁₀ (RDF+GM)	1.65	1.75	1.70	5.22	5.53	5.38	9.58	10.14	9.86	16.28	15.11	15.70	12.98	13.74	13.36	6.07	6.43	6.25
T ₁₁ (RDF+GM+AZOS)	1.73	1.83	1.78	5.32	5.63	5.48	9.61	10.21	9.91	16.84	16.74	16.79	13.44	14.23	13.84	8.99	9.51	9.25
T ₁₂ (1/3 RDF+GM+AZOS)	1.73	1.83	1.78	5.31	5.62	5.47	9.55	10.11	9.83	16.14	17.08	16.61	13.26	14.04	13.65	9.31	9.85	9.58
T ₁₃ (1/2 RDF+GM+AZOS)	1.60	1.70	1.65	5.20	5.51	5.36	9.45	10.07	9.76	15.79	15.49	15.64	12.29	13.01	12.65	5.76	6.10	5.93
General Mean	2.06	2.18		5.59	5.91		9.63	10.21		17.16	17.34		11.78	12.47		8.32	8.80	
S.Em	0.09	0.10		0.25	0.33		0.17	0.19		1.16	1.27		1.67	1.80		2.62	2.91	
C.D (0.05)	NS	NS		NS	NS		0.50	0.55		3.38	3.72		NS	NS		NS	NS	

Further, greater CGR was in general noticed during 2003-04, compared to 2002-03 at the different growth stages studied. The influence of different INM treatments studied in the present investigation was also found to be non-significant at 30-60 DAP, 60-90 DAP, 150-180 DAP and 180-210 DAP. However, significant influence of the treatments was recorded at 90-120 DAP and 120-150 DAP.

Among the treatments, T7 had recorded highest CGR during 2002-03 ($10.07 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($10.66 \text{ g m}^{-2}\text{day}^{-1}$) at 90-120 DAP. The treatments, T2 ($9.87 \text{ g m}^{-2}\text{day}^{-1}$), T3 ($9.92 \text{ g m}^{-2}\text{day}^{-1}$), T4 ($9.67 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($9.57 \text{ g m}^{-2}\text{day}^{-1}$), T8 ($9.94 \text{ g m}^{-2}\text{day}^{-1}$), T9 ($9.64 \text{ g m}^{-2}\text{day}^{-1}$), T10 ($9.58 \text{ g m}^{-2}\text{day}^{-1}$) and T11 ($9.61 \text{ g m}^{-2}\text{day}^{-1}$) during 2002-03; and T2 ($10.32 \text{ g m}^{-2}\text{day}^{-1}$), T3 ($10.46 \text{ g m}^{-2}\text{day}^{-1}$), T4 ($10.25 \text{ g m}^{-2}\text{day}^{-1}$), T5 ($10.13 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($10.52 \text{ g m}^{-2}\text{day}^{-1}$), T8 ($10.34 \text{ g m}^{-2}\text{day}^{-1}$), T9 ($10.20 \text{ g m}^{-2}\text{day}^{-1}$), T10 ($10.14 \text{ g m}^{-2}\text{day}^{-1}$), T11 ($10.21 \text{ g m}^{-2}\text{day}^{-1}$) and T12 ($10.11 \text{ g m}^{-2}\text{day}^{-1}$) during 2003-04 had also recorded CGR on a par with T7 treatment. However, lowest CGR was recorded for T1 treatment during 2002-03 ($8.82 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($9.33 \text{ g m}^{-2}\text{day}^{-1}$) at 90-120 DAP.

At 120-150 DAP, highest CGR was observed for T7 treatment during 2002-03 ($19.83 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($20.98 \text{ g m}^{-2}\text{day}^{-1}$). Further, the treatments, T2 ($16.91 \text{ g m}^{-2}\text{day}^{-1}$), T3 ($18.12 \text{ g m}^{-2}\text{day}^{-1}$), T4 ($17.83 \text{ g m}^{-2}\text{day}^{-1}$), T5 ($16.57 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($19.65 \text{ g m}^{-2}\text{day}^{-1}$), T8 ($19.21 \text{ g m}^{-2}\text{day}^{-1}$), T9 ($19.06 \text{ g m}^{-2}\text{day}^{-1}$) and T11 ($16.84 \text{ g m}^{-2}\text{day}^{-1}$) during 2002-03; and T3 ($18.86 \text{ g m}^{-2}\text{day}^{-1}$), T4 ($19.18 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($18.68 \text{ g m}^{-2}\text{day}^{-1}$), T8 ($20.01 \text{ g m}^{-2}\text{day}^{-1}$) and T9 ($18.37 \text{ g m}^{-2}\text{day}^{-1}$) during 2003-04 had recorded CGR on a par with T7 treatment. T1

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treatment had recorded lowest CGR during 2002-03 ($10.91 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($11.55 \text{ g m}^{-2}\text{day}^{-1}$).

4.2.10 Net assimilation rate (NAR)

The results are presented in Table 27. The influence of different INM treatments studied in the present investigation on NAR, at 30-60 DAP, 60-90 DAP, 150-180 DAP and 180-210 DAP was non-significant, while the effect at 90-120 DAP and 120-150 DAP was significant.

At 90-120 DAP, T7 treatment had recorded highest NAR during 2002-03 ($7.320 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($7.590 \text{ g m}^{-2}\text{day}^{-1}$). Further, lowest NAR was recorded by T1 ($4.870 \text{ g m}^{-2}\text{day}^{-1}$) during 2002-03 and 2003-04 ($5.010 \text{ g m}^{-2}\text{day}^{-1}$).

At 120-150 DAP also, T7 had recorded highest NAR during both 2002-03 ($10.450 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($12.840 \text{ g m}^{-2}\text{day}^{-1}$). The treatments, T3 ($10.420 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($10.050 \text{ g m}^{-2}\text{day}^{-1}$), T8 ($10.380 \text{ g m}^{-2}\text{day}^{-1}$) and T10 ($10.120 \text{ g m}^{-2}\text{day}^{-1}$) during 2002-03; and T3 ($12.560 \text{ g m}^{-2}\text{day}^{-1}$), T6 ($12.230 \text{ g m}^{-2}\text{day}^{-1}$), T8 ($12.760 \text{ g m}^{-2}\text{day}^{-1}$) and T9 ($12.490 \text{ g m}^{-2}\text{day}^{-1}$) during 2003-04 had recorded NAR on a par with T7 treatment. Further, T1 had recorded lowest NAR during both 2002-03 ($6.690 \text{ g m}^{-2}\text{day}^{-1}$) and 2003-04 ($8.930 \text{ g m}^{-2}\text{day}^{-1}$).

4.2.11 Shoot/root ratio

The results are presented in Table 28. A significant influence of the treatments studied was observed on shoot/root ratio during 2002-03 and 2003-04. T1 treatment had recorded highest shoot/root ratio during 2002-03 (1.48) and 2003-04 (1.45), while lowest shoot/root ratio was recorded by T7 during both 2002-03 (0.63) and 2003-04 (0.62). Further, T8 had also recorded lowest shoot/root ratio during

Table 27 : Net assimilation rate ($\text{g m}^{-2} \text{day}^{-1}$) at different growth stages in cassava as influenced by integrated nutrient management under irrigated conditions

Treatments	30-60 DAP			60-90 DAP			90-120 DAP			120-150 DAP			150-180 DAP			180-210 DAP		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	1.200	1.390	1.295	2.450	2.780	2.615	4.870	5.010	4.940	6.690	8.930	7.810	5.230	6.070	5.650	1.161	1.225
T ₂ (RDF+FYM)	1.620	1.780	1.700	2.290	2.800	2.545	5.850	6.050	5.950	9.020	11.470	10.245	4.990	5.890	5.440	1.492	1.610	1.551
T ₃ (RDF+FYM+AZOS)	1.720	1.830	1.775	2.050	2.310	2.180	6.040	6.170	6.105	10.420	12.560	11.490	4.860	5.760	5.310	2.210	2.470	2.340
T ₄ (1/3 RDF+FYM+AZOS)	1.760	2.050	1.905	2.060	2.560	2.310	5.830	6.090	5.960	9.270	10.890	10.080	5.100	5.950	5.525	2.300	2.560	2.430
T ₅ (1/2 RDF+FYM+AZOS)	1.420	1.780	1.600	2.310	2.840	2.575	5.390	5.540	5.465	8.230	9.750	8.990	5.140	5.990	5.565	1.209	1.308	1.258
T ₆ (RDF+VC)	1.460	1.710	1.585	2.080	2.290	2.185	6.430	6.790	6.610	10.050	12.230	11.140	4.890	5.820	5.355	2.140	2.440	2.290
T ₇ (RDF+VC+AZOS)	1.230	1.510	1.370	1.830	1.980	1.905	7.320	7.590	7.455	10.450	12.840	11.645	4.730	5.600	5.165	2.530	2.730	2.630
T ₈ (1/3 RDF+VC+AZOS)	1.250	1.630	1.440	1.810	2.180	1.995	6.820	7.050	6.935	10.380	12.760	11.570	4.920	5.670	5.295	2.880	2.980	2.930
T ₉ (1/2 RDF+VC+AZOS)	1.670	1.810	1.740	2.120	2.330	2.225	5.850	6.170	6.010	9.110	12.490	10.800	5.150	5.970	5.560	1.860	2.150	2.005
T ₁₀ (RDF+GM)	1.570	1.680	1.625	2.650	2.810	2.730	5.980	6.260	6.120	10.120	10.350	10.235	5.440	6.250	5.845	1.650	1.780	1.715
T ₁₁ (RDF+GM+AZOS)	1.640	1.660	1.650	2.580	2.750	2.665	5.450	6.070	5.760	8.190	11.210	9.700	5.320	6.170	5.745	2.110	2.170	2.140
T ₁₂ (1/3 RDF+GM+AZOS)	1.740	1.810	1.775	2.630	2.820	2.725	5.120	5.270	5.195	7.570	9.510	8.540	5.330	6.260	5.795	2.180	2.430	2.305
T ₁₃ (1/2 RDF+GM+AZOS)	1.930	2.110	2.020	2.870	3.020	2.945	4.930	5.150	5.040	7.160	9.040	8.100	5.380	6.200	5.790	1.670	1.860	1.765
General Mean	1.555	1.750		2.287	2.575		5.837	6.093		8.974	11.079		5.114	5.969		1.953	2.132	
S.Em	0.195	0.165		0.112	0.168		0.073	0.101		0.165	0.210		0.240	0.254		0.475	0.562	
C.D (0.05)	NS	NS		NS	NS		0.214	0.296		0.480	0.620		NS	NS		NS	NS	

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Table 28 : Shoot /root ratio in cassava as influenced by integrated nutrient management under irrigated conditions

Treatments	Shoot/root ratio		Mean
	02-03	03-04	
T ₁ (RDF)	1.48	1.45	1.46
T ₂ (RDF+FYM)	1.04	1.01	1.03
T ₃ (RDF+FYM+AZOS)	0.77	0.75	0.76
T ₄ ($\frac{2}{3}$ RDF+FYM+AZOS)	0.74	0.81	0.78
T ₅ ($\frac{1}{2}$ RDF+FYM+AZOS)	1.14	1.11	1.13
T ₆ (RDF+VC)	0.79	0.77	0.78
T ₇ (RDF+VC+AZOS)	0.63	0.62	0.63
T ₈ ($\frac{2}{3}$ RDF+VC+AZOS)	0.69	0.62	0.65
T ₉ ($\frac{1}{2}$ RDF+VC+AZOS)	0.90	0.87	0.88
T ₁₀ (RDF+GM)	1.02	1.02	1.02
T ₁₁ (RDF+GM+AZOS)	0.85	0.81	0.83
T ₁₂ ($\frac{2}{3}$ RDF+GM+AZOS)	1.13	0.82	0.98
T ₁₃ ($\frac{1}{2}$ RDF+GM+AZOS)	1.07	1.05	1.06
General Mean	0.94	0.90	
S.Em	0.12	0.13	
C.D (0.05)	0.35	0.38	

2003-04 (0.62). The treatments, T3 (0.77), T4 (0.74), T6 (0.79), T8 (0.69), T9 (0.90) and T11 (0.85) during 2002-03; and T3 (0.75), T4 (0.81), T6 (0.77), T9 (0.87), T11 (0.81) and T12 (0.82) during 2003-04 had also recorded shoot/root ratio on a par with T7 treatment.

4.2.12 Yield and yield attributes

The experimental results obtained with regards to the effect of different INM treatments on number of tubers per plant, tuber length, tuber girth, tuber weight per plant and yield per hectare are presented in Table 29.

4.2.12.1 Number of tubers per plant

The number of tubers per plant was in general observed to be higher during 2003-04 (8.61), compared to 2002-03 (8.50). A significant influence of the different treatments studied in the present investigation was also observed on number of tubers per plant during 2002-03 and 2003-04. Among the treatments, T7 had recorded highest number of tubers per plant during both 2002-03 (9.21) and 2003-04 (9.17). The treatments, T3 (8.81), T6 (8.82) and T8 (9.00) during 2002-03, and T3 (8.73), T4 (8.70), T6 (9.01), T8 (8.95) and T9 (8.86) during 2003-04 had also recorded number of tubers per plant on a par with T7 treatment. Lowest number of tubers per plant was recorded by T1 during 2002-03 (7.42) and 2003-04 (8.00).

4.2.12.2 Tuber length

Tuber length was in general observed to be higher during 2003-04 (27.40 cm), compared to 2002-03 (27.29 cm). A significant influence of the different treatments studied in the present investigation was also observed on tuber length during 2002-03 and 2003-04. Among the treatments, T7 had recorded highest tuber

Table 29 : Yield and yield attributes in cassava as influenced by integrated nutrient management under irrigated conditions

Treatments	Number of tubers per plant			Tuber length (cm)			Tuber diameter (cm)			Fresh to dry weight of tubers (%)			Tuber weight per plant (kg)			Yield per hectare (tonnes)		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	7.42	8.00	7.71	23.11	22.85	22.98	8.28	8.47	8.38	32.16	32.98	32.57	1.87	1.93	1.90	21.71	25.24	23.48
T ₂ (RDF+FYM)	8.32	8.47	8.40	27.20	26.50	26.85	9.06	10.03	9.55	33.80	34.76	34.28	2.64	2.76	2.70	26.83	32.27	29.55
T ₃ (RDF+FYM+AZOS)	8.81	8.73	8.77	29.10	28.44	28.77	9.89	10.46	10.18	35.18	36.68	35.93	2.89	2.90	2.90	30.04	35.01	32.53
T ₄ (1/3 RDF+FYM+AZOS)	8.63	8.70	8.67	27.04	28.15	27.60	9.58	9.87	9.73	34.86	35.17	35.02	2.84	2.92	2.88	29.06	34.25	31.66
T ₅ (1/2 RDF+FYM+AZOS)	8.53	8.49	8.51	26.59	25.89	26.24	9.37	9.83	9.60	33.98	34.92	34.45	2.45	2.50	2.48	25.50	29.59	27.55
T ₆ (RDF+VC)	8.82	9.01	8.92	28.92	29.30	29.11	9.25	10.13	9.69	34.72	35.86	35.29	2.76	3.04	2.90	32.08	34.78	33.43
T ₇ (RDF+VC+AZOS)	9.21	9.17	9.19	30.12	31.16	30.64	10.46	10.87	10.67	36.54	37.06	36.80	3.36	3.21	3.29	35.49	37.10	36.30
T ₈ (1/3 RDF+VC+AZOS)	9.00	8.95	8.98	29.24	30.08	29.66	10.38	10.31	10.35	35.17	36.48	35.83	3.27	3.17	3.22	33.12	36.17	34.65
T ₉ (1/2 RDF+VC+AZOS)	8.69	8.86	8.78	27.62	28.64	28.13	9.93	10.15	10.04	34.90	33.87	34.39	2.58	2.93	2.76	31.25	33.07	32.16
T ₁₀ (RDF+GM)	8.21	8.35	8.28	26.52	26.10	26.31	8.51	9.54	9.03	32.67	33.74	33.21	2.43	2.59	2.51	25.80	28.16	26.98
T ₁₁ (RDF+GM+AZOS)	8.47	8.51	8.49	27.89	27.77	27.83	9.00	10.18	9.59	33.13	35.16	34.65	2.81	2.77	2.79	27.83	31.44	29.64
T ₁₂ (1/3 RDF+GM+AZOS)	8.41	8.46	8.44	26.14	26.50	26.32	8.72	9.98	9.35	33.56	34.53	34.05	2.74	2.67	2.71	27.25	30.13	28.69
T ₁₃ (1/2 RDF+GM+AZOS)	8.02	8.25	8.14	25.31	24.79	25.05	8.51	9.51	9.01	33.28	32.68	32.98	2.38	2.34	2.36	23.70	26.59	25.15
General Mean	8.50	8.61		27.29	27.40		9.29	9.96		34.23	34.91		2.69	2.75		28.44	31.83	
S.Em	0.17	0.18		0.83	1.12		0.44	0.42		0.90	0.88		0.19	0.17		0.82	0.93	
C.D (0.05)	0.50	0.53		2.43	3.28		1.27	1.22		NS	NS		0.55	0.50		2.38	2.70	

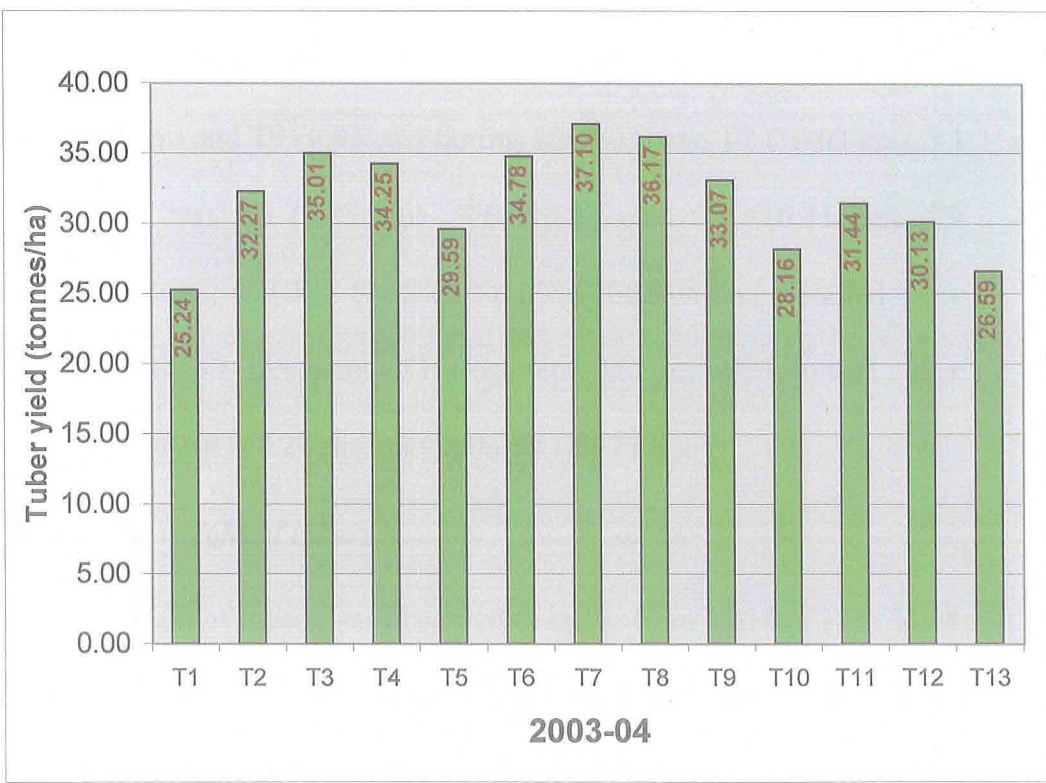
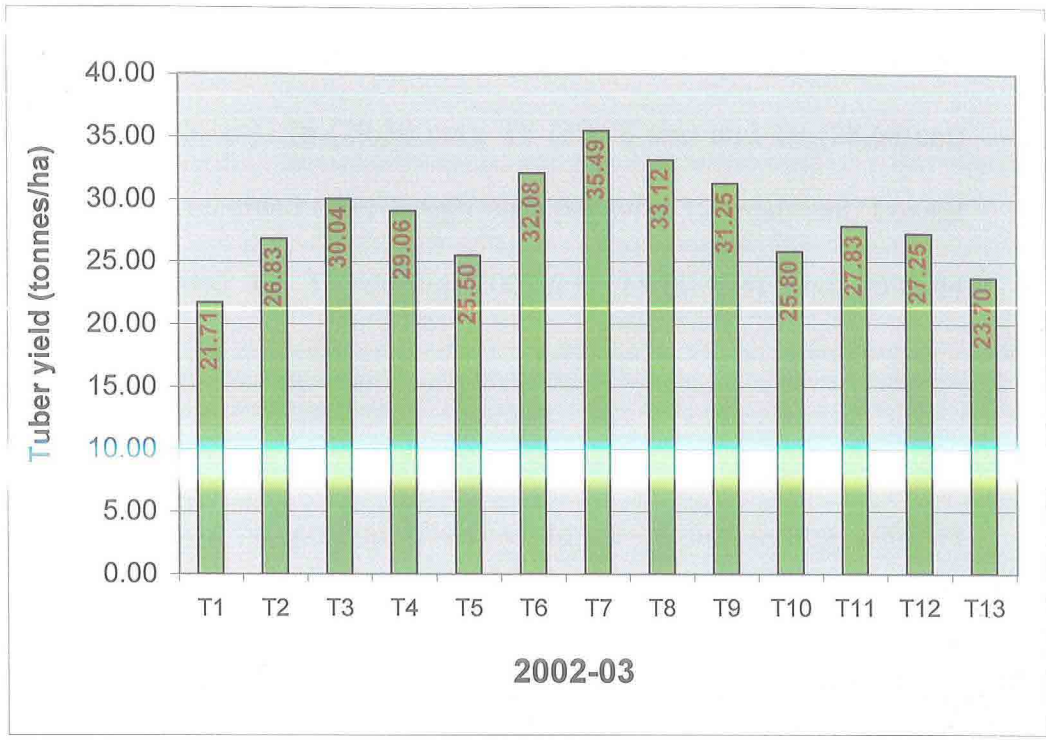


Fig. 12. Tuber yield (tonnes/ha) of cassava as influenced by integrated nutrient management under irrigated conditions

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length during both 2002-03 (30.12 cm) and 2003-04 (31.16 cm). The treatments, T3 (29.10 cm), T6 (28.92 cm), T8 (29.24 cm) and T11 (27.89 cm) during 2002-03; and T3 (28.44 cm), T4 (28.15 cm), T6 (29.30 cm), T8 (30.08 cm) and T9 (28.64 cm) during 2003-04 had also recorded tuber length on a par with T7 treatment. Lowest tuber length was recorded by T1 during 2002-03 (23.11 cm) and 2003-04 (22.85 cm).

4.2.12.3 Tuber diameter

Tuber diameter was in general observed to be higher during 2003-04 (9.96 cm), compared to 2002-03 (9.29 cm). Further, a significant influence of the INM treatments was observed for the character. Among the treatments, T7 had recorded highest tuber girth during both 2002-03 (10.46 cm) and 2003-04 (10.87 cm). Further, the treatments T3 (9.89 cm), T4 (9.58 cm), T5 (9.37 cm), T6 (9.25 cm), T8 (10.38 cm) and T9 (9.93 cm) during 2002-03; and T2 (10.03 cm), T3 (10.46 cm), T4 (9.87 cm), T5 (9.83 cm) T6 (10.13 cm), T8 (10.31 cm), T9 (10.15 cm), T11 (10.18 cm) and T12 (9.98 cm) during 2003-04 had recorded tuber diameter on a par with T7 treatment. T1 treatment had recorded lowest tuber diameter during both 2002-03 (8.28 cm) and 2003-04 (8.47 cm).

4.2.12.4 Fresh to dry weight of tubers

Fresh to dry weight of tubers was observed to range from 32.16 (T1) to 36.54 per cent (T7) with a mean of 34.23 per cent during 2002-03 and from 32.98 (T1) to 37.06 per cent (T7) with a mean of 34.91 per cent. However, different INM treatments studied in the present investigation did not exert any significant influence on tuber dry mater content during both the years of study.

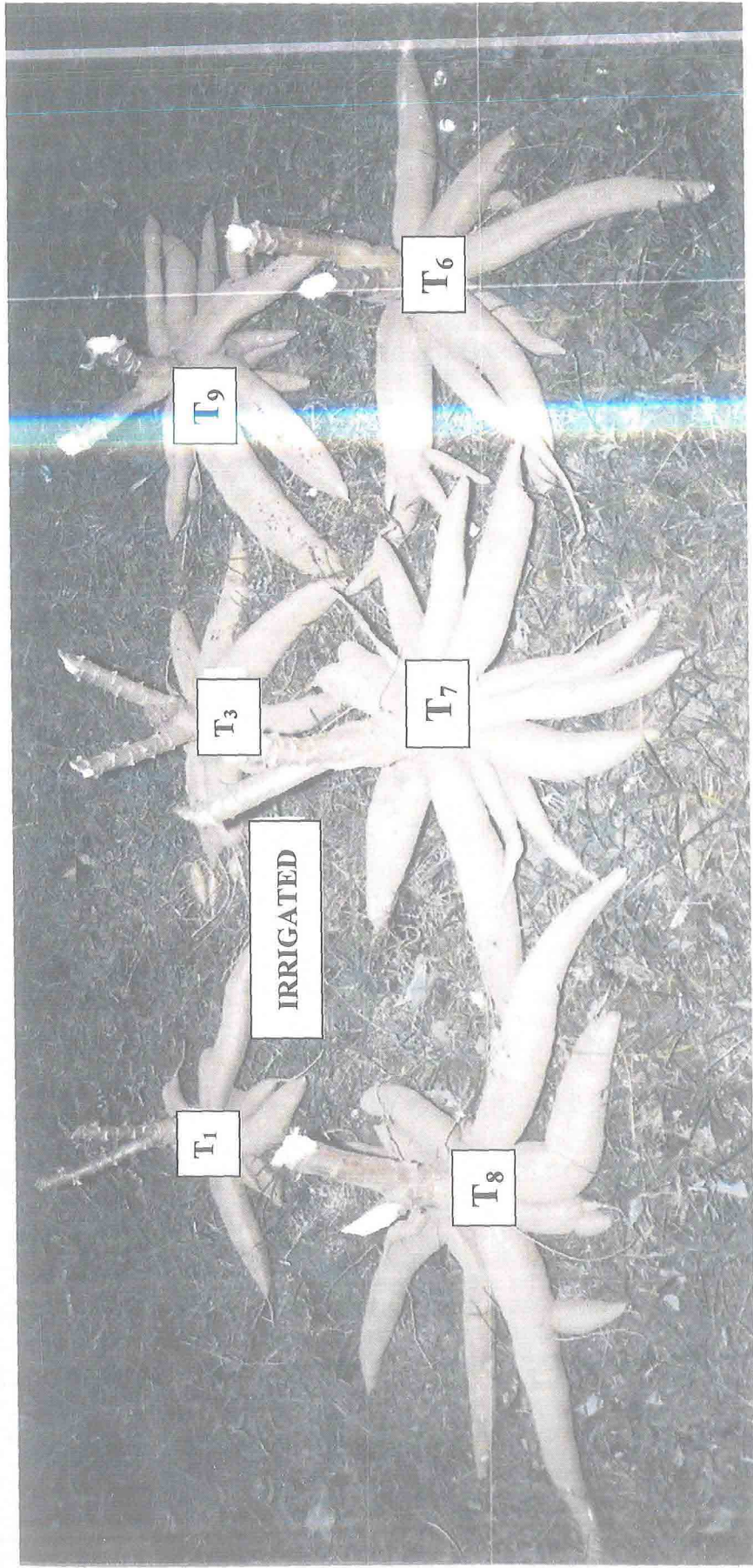


Plate 4. Cassava tuber yield per plant in the superior integrated nutrient management treatments and application of inorganics alone (T1) during 2002-03

4.2.12.5 *Tuber weight per plant*

Higher tuber weight per plant was in general observed to be higher during 2003-04 (2.75 kg), compared to 2002-03 (2.69 kg). Further, a significant effect of the different INM treatments studied was observed for the character. Among the treatments, T7 had recorded highest tuber weight per plant during both 2002-03 (3.36 kg) (Plate 4) and 2003-04 (3.21 kg) (Plate 5). Further, the treatments T3 (2.89 kg), T4 (2.84 kg), T8 (3.27 kg) and T11 (2.81 kg) during 2002-03; and T2 (2.76 kg), T3 (2.90 kg), T4 (2.92 kg), T6 (3.04 kg), T8 (3.17 kg), T9 (2.93 kg) and T11 (2.77 kg) during 2003-04 had also recorded tuber weight per plant on a par with T7 treatment. Lowest tuber weight per plant was recorded by T1 treatment during both 2002-03 (1.87 kg) and 2003-04 (1.93 kg).

4.2.13 *Yield per hectare*

The tuber yield (Table 29 and Fig.12) was in general noticed to be higher during 2003-04 (31.83 t), compared to 2002-03 (28.54 t). Further, a significant influence of the different INM treatments studied in the present investigation was recorded for the character. Among the treatments, T7 had recorded highest tuber yield per hectare during both 2002-03 (35.49 t) and 2003-04 (37.10 t). The treatment, T8 (33.12 t) during 2002-03; and T3 (35.01 t), T6 (34.78 t) and T8 (36.17 t) during 2003-04 had recorded tuber yield per hectare on a par with T7 treatment. However, T1 treatment had recorded lowest yield per hectare during both 2002-03 (21.71 t) and 2003-04 (25.24 t).

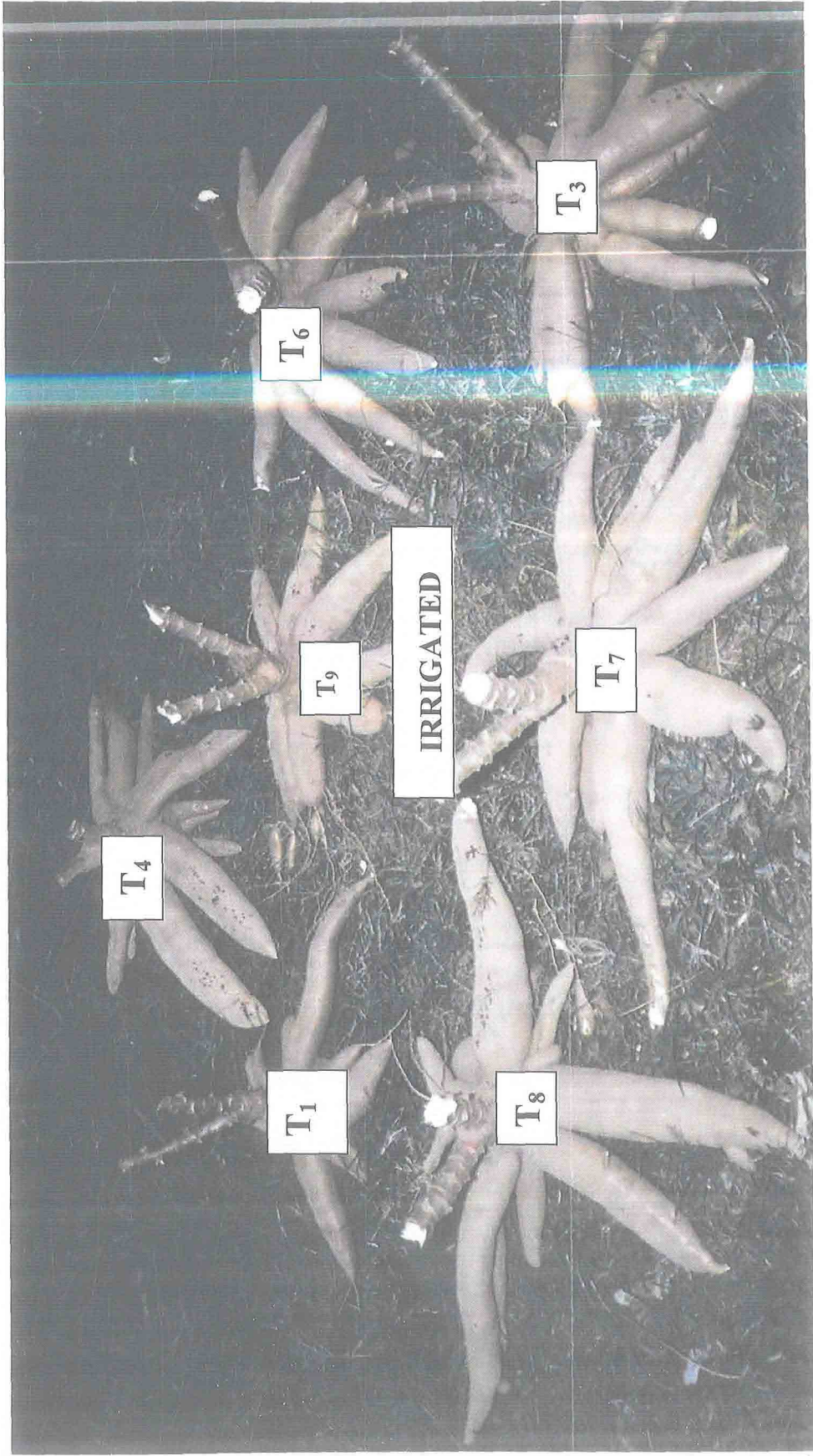


Plate 5. Cassava tuber yield per plant in the superior integrated nutrient management treatments and application of inorganics alone (T1) during 2003-04

4.2.14 Quality attributes

The results pertaining to influence of the different INM treatments on quality attributes namely, starch content, hydrocyanin content, crude fibre content and cooking time are presented in Table 30.

4.2.14.1 Starch content

The starch content of cassava was in general noticed to be higher during 2003-04, compared to 2002-03. Further, the starch content under different INM treatments was observed to range from 28.07 per cent (T1) to 33.04 per cent (T7) with an average of 30.76 per cent during 2002-03; and from 28.80 per cent (T1) to 33.55 per cent (T7) with an average of 31.66 per cent during 2003-04. However, the effect of different INM treatments on starch content of cassava was noticed to be non-significant. (Fig.13).

4.2.14.2 Hydrocyanin content (HCN)

The HCN content of cassava tuber was in general observed to be higher during 2003-04 (37.82 $\mu\text{g/g}$), compared to 2002-03 (37.15 $\mu\text{g/g}$). Further, the hydrocyanin content was observed to range from 35.35 $\mu\text{g/g}$ (T11) to 39.58 $\mu\text{g/g}$ (T2) during 2002-03; and 35.44 $\mu\text{g/g}$ (T1) to 38.65 $\mu\text{g/g}$ (T8) during 2003-04. However, the influence of different INM treatments on HCN content of cassava tubers was observed to be non-significant during both the years of investigation (Fig.13).

4.2.14.3 Crude fibre content

Crude fibre content of cassava tuber was observed to range from 0.59 per cent (T5) to 0.80 per cent (T11) with an average of 0.69 per cent during

Table 30 : Quality attributes in cassava as influenced by integrated nutrient management under irrigated conditions

Treatments	Starch content (%)			Hydrocyanin content (µg/g)			Crude fibre content (%)			Cooking time		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	28.07	28.80	28.44	36.18	35.44	35.81	0.72	0.69	0.71	30.00	29.00
T ₂ (RDF+FYM)	32.30	31.75	32.03	39.58	38.27	38.93	0.67	0.75	0.71	31.00	29.67	30.34
T ₃ (RDF+FYM+AZOS)	32.21	32.32	32.27	38.10	38.37	38.24	0.66	0.76	0.71	31.33	30.00	30.67
T ₄ (1/3 RDF+FYM+AZOS)	32.30	32.51	32.41	37.72	37.92	37.82	0.64	0.57	0.61	28.67	29.00	28.84
T ₅ (1/2 RDF+FYM+AZOS)	29.17	30.89	30.03	38.57	38.40	38.49	0.59	0.88	0.74	28.33	29.33	28.83
T ₆ (RDF+VC)	31.12	33.43	32.28	37.28	38.61	37.95	0.64	0.91	0.78	30.67	28.67	29.67
T ₇ (RDF+VC+AZOS)	33.04	33.55	33.30	37.46	38.52	37.99	0.68	0.63	0.66	30.67	28.67	29.67
T ₈ (1/3 RDF+VC+AZOS)	32.83	33.15	32.99	37.38	38.65	38.02	0.71	0.83	0.77	28.33	29.00	28.67
T ₉ (1/2 RDF+VC+AZOS)	30.88	30.69	30.79	36.25	37.44	36.85	0.78	0.61	0.70	28.00	29.67	28.84
T ₁₀ (RDF+GM)	29.23	30.25	29.74	36.36	37.77	37.07	0.66	0.58	0.62	29.33	28.00	28.67
T ₁₁ (RDF+GM+AZOS)	30.77	31.39	31.08	35.35	37.62	36.49	0.80	0.68	0.74	29.33	28.67	29.00
T ₁₂ (1/3 RDF+GM+AZOS)	29.45	32.42	30.94	36.36	38.03	37.20	0.78	0.65	0.72	28.00	30.00	29.00
T ₁₃ (1/2 RDF+GM+AZOS)	28.57	30.43	29.50	36.32	36.63	36.48	0.67	0.68	0.68	27.33	29.00	28.17
General Mean	30.76	31.66		37.15	37.82		0.69	0.71		29.31	29.13	
S.E.m	1.02	1.04		0.84	0.67		0.06	0.13		1.25	1.06	
C.D (0.05)	NS	NS		NS	NS		NS	NS		NS	NS	

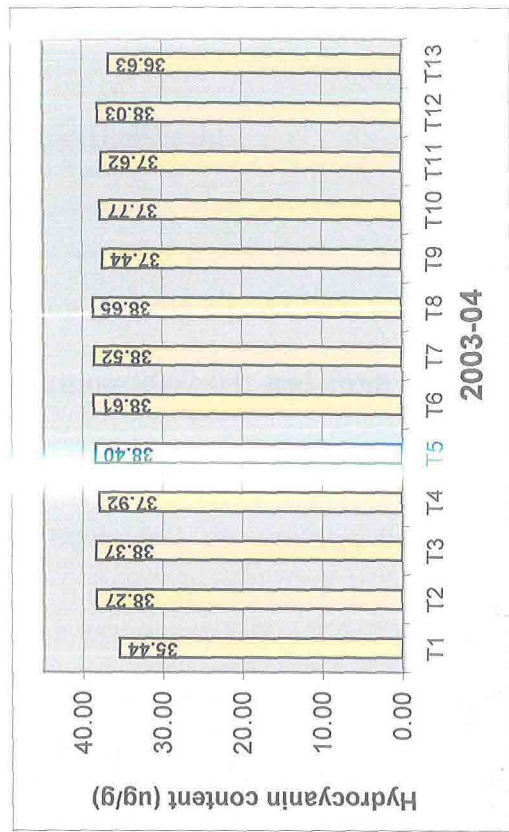
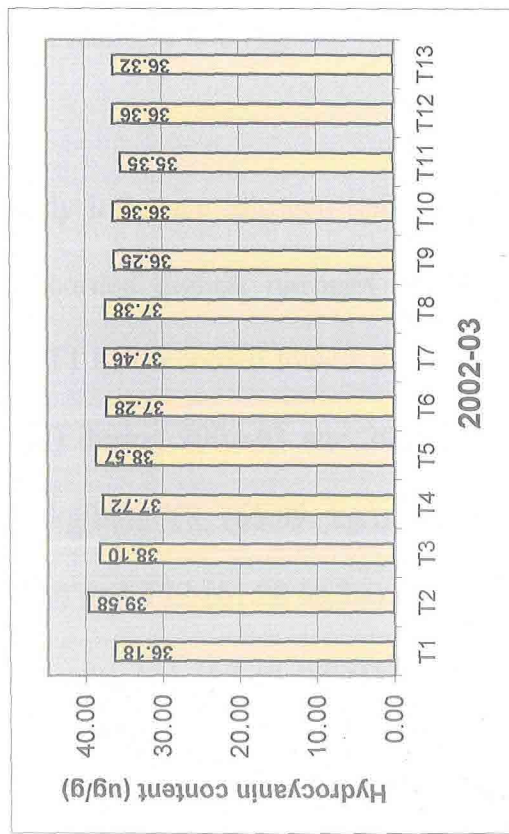
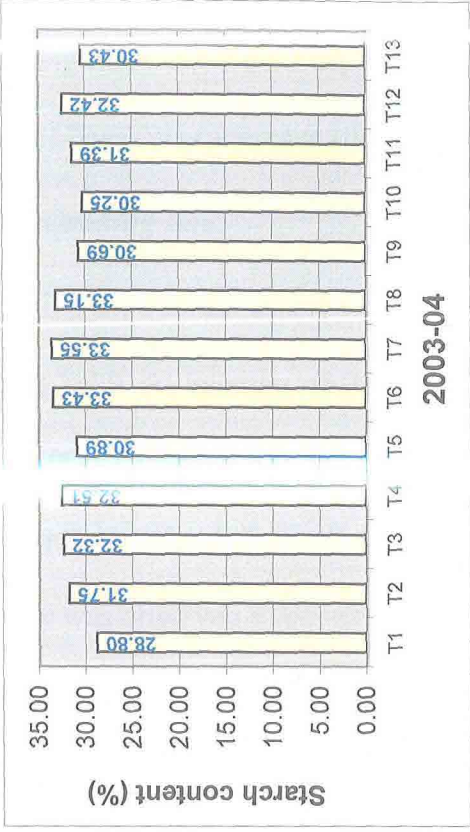
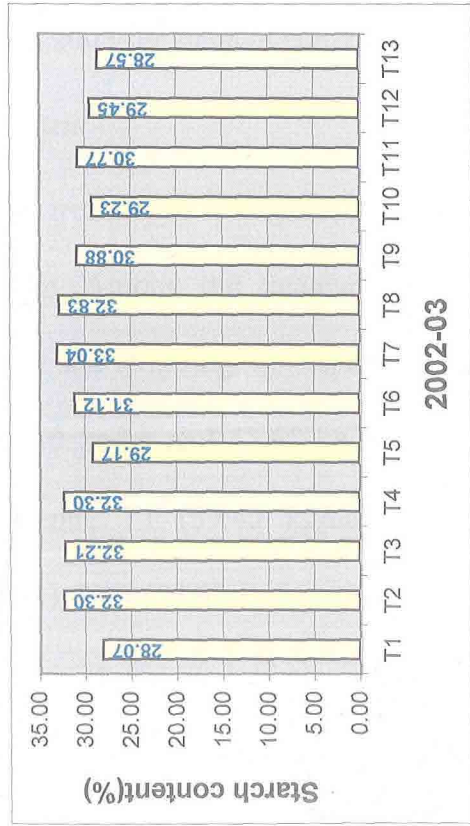


Fig. 13. Quality attributes of cassava as influenced by integrated nutrient management under irrigated conditions

2002-03; and from 0.57 per cent (T4) to 0.91 per cent (T6) with an average of 0.71 per cent during 2003-04. However, the effect of different INM treatments on crude fibre content of cassava tubers was observed to be non-significant.

4.2.14.4 Cooking time

Cooking time of the tubers was observed to range from 27.33 (T13) to 31.33 (T3) minutes with an average of 29.31 minutes during 2002-03; and from 28.00 (T10) to 30.00 (T3 and T12) minutes with an average of 29.13 minutes during 2003-04. However, the effect of different INM treatments on cooking time of cassava tuber was observed to be non-significant.

4.2.15 Nitrogen uptake

The experimental results regarding influence of different INM treatments on nitrogen uptake by cassava stem, leaf and tuber in addition to total uptake during 2002-03 and 2003-04 years of study are presented in Table 31 and Fig.14.

4.2.15.1 Stem

INM treatments were noticed to significantly influence nitrogen uptake by cassava stem. Among the treatments, T7 had recorded highest nitrogen uptake (67.53 kg/ha and 69.29 kg/ha, respectively), while T1 had recorded lowest nitrogen uptake (45.40 kg/ha and 45.65 kg/ha, respectively) during 2002-03 and 2003-04. The treatments, T3 (59.40 kg/ha), T6 (60.59 kg/ha), T8 (65.89 kg/ha), T9 (63.02 kg/ha), T10 (58.93 kg/ha), T11 (60.81 kg/ha) and T12 (61.28 kg/ha) during 2002-03; and T6 (61.80 kg/ha), T8 (65.41 kg/ha) and T11 (62.29 kg/ha) during 2003-04 had recorded nitrogen uptake on a par with T7 treatment.

Table 31 : Nitrogen uptake (kg/ha) in cassava as influenced by integrated nutrient management under irrigated conditions

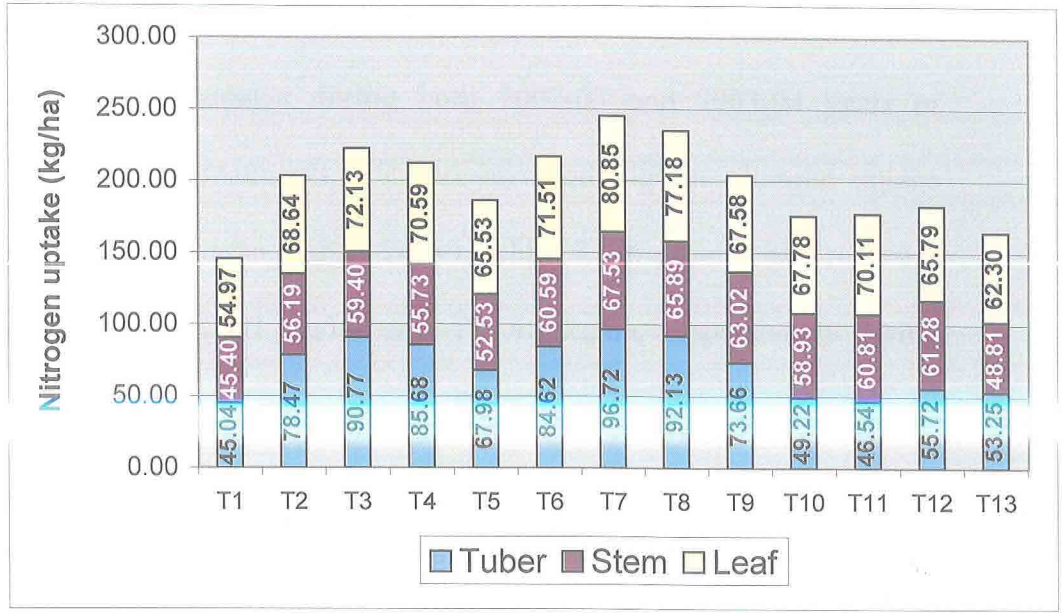
Treatments	Stem			Leaf			Tuber			Total uptake		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	45.40	45.65	45.53	54.97	60.73	57.85	45.04	48.10	46.57	145.41	154.48
T ₂ (RDF+FYM)	56.19	58.21	57.20	68.64	69.81	69.23	78.47	83.43	80.95	203.30	211.45	207.38
T ₃ (RDF+FYM+AZOS)	59.40	60.18	59.79	72.13	66.93	69.53	90.77	92.15	91.46	222.30	219.26	220.78
T ₄ (1/3 RDF+FYM+AZOS)	55.73	58.00	56.87	70.59	76.00	73.30	85.68	87.94	86.81	212.00	221.94	216.97
T ₅ (1/2 RDF+FYM+AZOS)	52.53	53.21	52.87	65.53	74.32	69.93	67.98	69.36	68.67	186.04	196.89	191.47
T ₆ (RDF+VC)	60.59	61.80	61.20	71.51	86.75	79.13	84.62	87.36	85.99	216.72	235.91	226.32
T ₇ (RDF+VC+AZOS)	67.53	69.29	68.41	80.85	86.75	83.80	96.72	98.54	97.63	245.10	254.58	249.84
T ₈ (1/3 RDF+VC+AZOS)	65.89	65.41	65.65	77.18	79.12	78.15	92.13	93.49	92.81	235.20	238.02	236.61
T ₉ (1/2 RDF+VC+AZOS)	63.02	60.49	61.76	67.58	86.61	77.10	73.66	75.01	74.34	204.26	222.11	213.19
T ₁₀ (RDF+GM)	58.93	52.37	55.65	67.78	82.28	75.03	49.22	51.05	50.14	175.93	185.70	180.82
T ₁₁ (RDF+GM+AZOS)	60.81	62.29	61.55	70.11	69.14	69.63	46.54	60.84	53.69	177.46	192.27	184.87
T ₁₂ (1/3 RDF+GM+AZOS)	61.28	49.20	55.24	65.79	60.73	63.26	55.72	57.86	56.79	182.79	167.79	175.29
T ₁₃ (1/2 RDF+GM+AZOS)	48.81	48.73	48.77	62.30	60.73	61.52	53.25	55.72	54.49	164.36	165.18	164.77
General Mean	58.16	57.29		68.84	73.84		70.75	73.91		197.76	205.04	
S.E.m	3.48	2.57		3.24	4.31		6.79	5.97		12.76	7.47	
C.D (0.05)	10.16	7.50		9.46	12.58		19.80	17.41		37.25	21.80	

4.2.15.2 Leaf

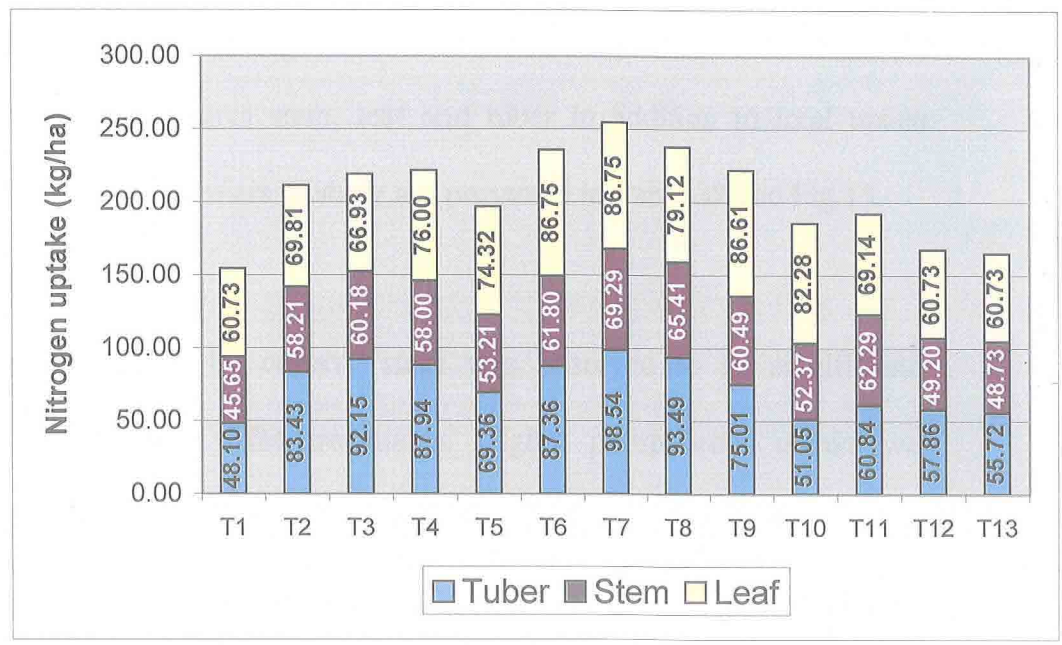
Significant influence of different INM treatments imposed in the present study was observed on nitrogen uptake by cassava leaf during both 2002-03 and 2003-04 years of investigation. Nitrogen uptake by cassava leaf was observed to be higher during 2003-04 (73.84 kg/ha), compared to 2002-03 (68.84 kg/ha). Among the treatments, T7 had recorded highest nitrogen uptake (80.85 kg/ha and 86.75 kg/ha, respectively), while T1 had recorded lowest nitrogen uptake (54.97 kg/ha and 60.73 kg/ha, respectively) during 2002-03 and 2003-04. T6 (86.75 kg/ha) had also recorded highest uptake during 2003-04. Further, the treatments, T3 (72.13 kg/ha), T6 (71.51 kg/ha) and T8 (77.18 kg/ha) during 2002-03; and T4 (76.00 kg/ha), T5 (74.32 kg/ha), T8 (79.12 kg/ha), T9 (86.61 kg/ha) and T10 (82.28 kg/ha) during 2003-04 had recorded nitrogen uptake on a par with T7 treatment.

4.2.15.3 Tuber

The different INM treatments studied in the present investigation were observed to exert a significant influence on the nitrogen uptake by cassava tuber during both 2002-03 and 2003-04 years of investigation. Among the treatments, T7 had recorded highest nitrogen uptake (96.72 kg/ha and 98.54 kg/ha, respectively), while T1 had recorded lowest nitrogen uptake (45.04 kg/ha and 48.10 kg/ha, respectively) during 2002-03 and 2003-04. The treatments, T3 (90.77 kg/ha), T4 (85.68 kg/ha), T6 (84.62 kg/ha) and T8 (92.13 kg/ha) during 2002-03; and T2 (83.43 kg/ha), T3 (92.15 kg/ha), T4 (87.94 kg/ha), T6 (87.36 kg/ha) and T8 (93.49 kg/ha) during 2003-04 had recorded nitrogen uptake on a par with T7 treatment.



2002-03



2003-04

Fig.14. Nitrogen uptake (kg/ha) in cassava as influenced by integrated nutrient management under irrigated conditions

4.2.15.4 Total

A significant influence of different INM treatments studied was observed on total nitrogen uptake by cassava during both 2002-03 and 2003-04 years of investigation. Among the treatments, T7 had recorded highest nitrogen uptake (245.10 kg/ha and 254.58 kg/ha, respectively), while T1 treatment had recorded lowest nitrogen uptake (145.41 kg/ha and 154.48 kg/ha, respectively) during 2002-03 and 2003-04 years of investigation. Further, the treatments, T3 (222.30 kg/ha), T4 (212.00 kg/ha), T6 (216.72 kg/ha) and T8 (235.20 kg/ha) during 2002-03; and T6 (235.91 kg/ha) and T8 (238.02 kg/ha) during 2003-04 had also recorded uptake on a par with T7 treatment.

4.2.16 Phosphorous uptake

The experimental results regarding influence of different INM treatments on phosphorous uptake by cassava stem, leaf and tuber in addition to total uptake during 2002-03 and 2003-04 years of study are presented in Table 32 and Fig.15.

4.2.16.1 Stem

Phosphorous uptake by cassava stem was observed to be significantly influenced by the different INM treatments. Higher phosphorous uptake was recorded during 2003-04 (16.62 kg/ha), compared to 2002-03 (15.96 kg/ha). Among the treatments, T7 had recorded highest phosphorous uptake (18.81 kg/ha and 19.94 kg/ha, respectively), while T13 had recorded lowest phosphorous uptake (13.92 kg/ha and 14.16 kg/ha, respectively) during 2002-03 and 2003-04 years of study. Further, T2 (15.53 kg/ha), T3 (17.17 kg/ha), T4 (16.18 kg/ha), T5 (15.81 kg/ha), T6 (17.93 kg/ha), T8 (17.33 kg/ha) and T9 (16.86 kg/ha) during 2002-03;

Table 32 : Phosphorous uptake (kg/ha) in cassava as influenced by integrated nutrient management under irrigated conditions

Treatments	Stem			Leaf			Tuber			Total uptake		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	14.33	14.60	14.47	8.12	9.21	8.67	9.31	10.35	9.83	31.76	34.16
T ₂ (RDF+FYM)	15.53	16.09	15.81	9.30	10.47	9.89	12.05	14.79	13.42	36.88	41.35	39.12
T ₃ (RDF+FYM+AZOS)	17.17	17.94	17.56	11.21	11.53	11.37	18.27	18.19	18.23	46.65	47.66	47.16
T ₄ (1/3 RDF+FYM+AZOS)	16.18	16.83	16.51	10.45	11.19	10.82	15.42	16.24	15.83	42.05	44.26	43.16
T ₅ (1/2 RDF+FYM+AZOS)	15.81	16.19	16.00	8.75	10.38	9.57	13.03	16.01	14.52	37.59	42.58	40.09
T ₆ (RDF+VC)	17.93	16.95	17.44	9.61	11.08	10.35	16.84	19.21	18.03	44.38	47.24	45.81
T ₇ (RDF+VC+AZOS)	18.81	19.94	19.38	11.36	12.19	11.78	20.42	23.24	21.83	50.59	55.37	52.98
T ₈ (1/3 RDF+VC+AZOS)	17.33	18.11	17.72	10.10	11.87	10.99	18.19	21.47	19.83	45.62	51.45	48.54
T ₉ (1/2 RDF+VC+AZOS)	16.86	17.83	17.35	9.23	11.29	10.26	16.72	19.08	17.90	42.81	48.20	45.51
T ₁₀ (RDF+GM)	14.28	15.46	14.87	8.36	10.76	9.56	12.05	14.41	13.22	34.69	40.63	37.66
T ₁₁ (RDF+GM+AZOS)	15.21	16.55	15.88	8.59	10.89	9.74	12.70	16.69	14.70	36.50	44.13	40.32
T ₁₂ (1/3 RDF+GM+AZOS)	14.07	15.39	14.73	8.27	10.43	9.35	11.22	11.48	11.35	33.56	37.30	35.43
T ₁₃ (1/2 RDF+GM+AZOS)	13.92	14.16	14.04	7.63	9.03	8.33	7.00	8.27	7.64	28.55	31.46	30.01
General Mean	15.96	16.62		9.31	10.79		14.09	16.11		39.36	43.52	
S.E.m	1.20	0.85		0.37	0.46		1.94	2.09		1.77	1.95	
C.D (0.05)	3.51	2.49		1.08	1.35		5.67	6.11		5.16	5.69	

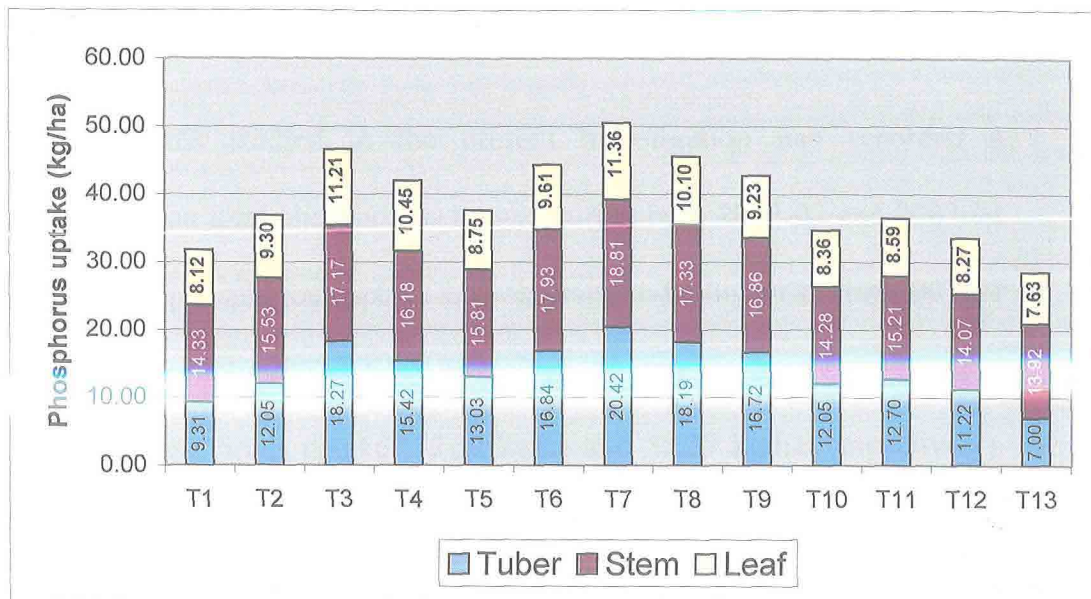
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and T3 (17.94 kg/ha), T8 (18.11 kg/ha) and T9 (17.83 kg/ha) during 2003-04 had recorded phosphorous uptake on a par with T7 treatment.

4.2.16.2 Leaf

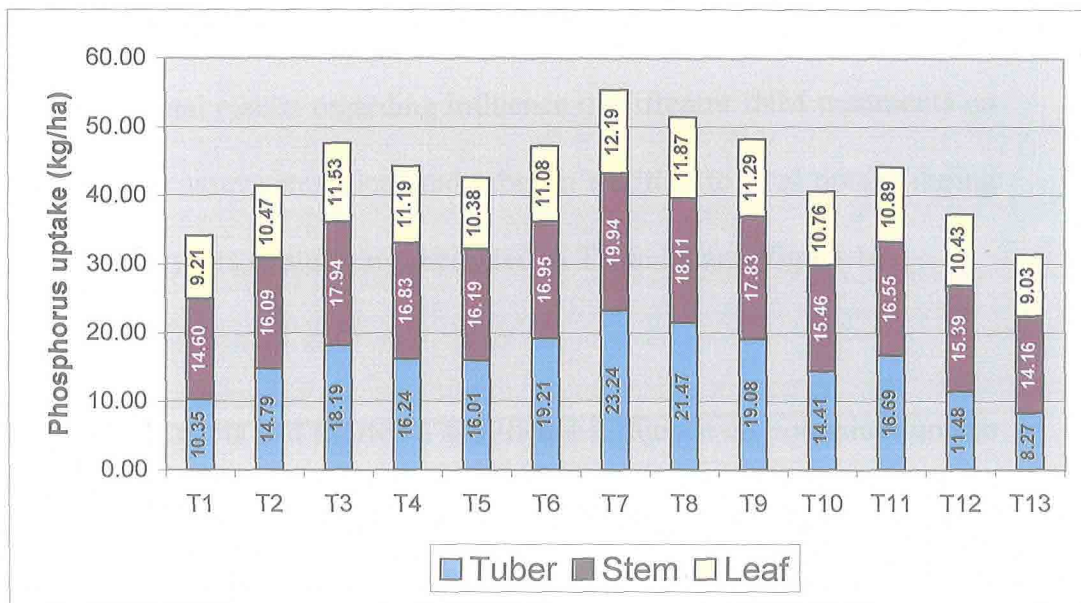
A significant influence of the different INM treatments imposed in the present investigation was observed on phosphorous uptake by cassava leaf during both 2002-03 and 2003-04 years of investigation. Higher phosphorous uptake by cassava leaf was observed during 2003-04 (10.79 kg/ha), compared to 2002-03 (9.31 kg/ha). Among the treatments, T7 had recorded highest uptake (11.36 kg/ha and 12.19 kg/ha, respectively), while T13 had recorded lowest uptake (7.63 kg/ha and 9.03 kg/ha, respectively) during 2002-03 and 2003-04. Further, T3 (11.21 kg/ha) and T4 (10.45 kg/ha) during 2002-03; and T3 (11.53 kg/ha), T4 (11.19 kg/ha), T6 (11.08 kg/ha), T8 (11.87 kg/ha), T9 (11.29 kg/ha) and T11 (10.89 kg/ha) during 2003-04 had recorded phosphorous uptake on a par with T7 treatment.

4.2.16.3 Tuber

INM treatments studied in the present investigation had exerted significant influence on phosphorous uptake by cassava tuber during both 2002-03 and 2003-04 years of investigation. Higher phosphorous uptake was observed during 2003-04 (16.11 kg/ha), compared to 2002-03 (14.09 kg/ha). Among the treatments, T7 had recorded highest uptake (20.42 kg/ha and 23.24 kg/ha, respectively), while T13 had recorded lowest uptake (7.00 kg/ha and 8.27 kg/ha, respectively) during both 2002-03 and 2003-04 years of investigation. Further, T3 (18.27 kg/ha), T4 (15.42 kg/ha), T6 (16.84 kg/ha), T8 (18.19 kg/ha) and T9 (16.72 kg/ha) during 2002-03; and T3



2002-03



2003-04

Fig. 15. Phosphorus uptake (kg/ha) in cassava as influenced by integrated nutrient management under irrigated conditions

(18.19 kg/ha), T6 (19.21 kg/ha), T8 (21.47 kg/ha) and T9 (19.08 kg/ha) during 2003-04 had recorded phosphorous uptake on a par with T7 treatment.

4.2.16.4 Total

INM treatments studied in the present investigation had recorded a significant influence on total phosphorous uptake during both 2002-03 and 2003-04 years of study. Total phosphorous uptake was observed to be higher during 2003-04 (43.52 kg/ha), compared to 2002-03 (39.36 kg/ha). Among the treatments, T7 had recorded highest phosphorous uptake (50.59 kg/ha and 55.37 kg/ha, respectively), while T13 had recorded lowest uptake (28.55 kg/ha and 31.46 kg/ha, respectively) during both 2002-03 and 2003-04. Further, T3 (46.65 kg/ha) and T8 (45.62 kg/ha) during 2002-03; and T8 (51.45 kg/ha) during 2003-04 had recorded phosphorous uptake on a par with T7 treatment.

4.2.17 Potassium uptake

The experimental results regarding influence of different INM treatments on potassium uptake by cassava stem, leaf and tuber in addition to total uptake during 2002-03 and 2003-04 years of study are presented in Table 33 and Figure 16.

4.2.17.1 Stem

The INM treatments had exerted a significant influence on potassium uptake by cassava stem during 2002-03 and 2003-04 years of investigation. Higher potassium uptake was noticed during 2003-04 (61.52 kg/ha), compared to 2002-03 (48.92 kg/ha). Among the treatments, T7 had recorded highest potassium uptake (53.17 kg/ha and 71.60 kg/ha, respectively), while T13 had recorded lowest potassium uptake (45.32 kg/ha and 48.77 kg/ha, respectively) during 2002-03 and

Table 33 : Potassium uptake (kg/ha) in cassava as influenced by integrated nutrient management under irrigated conditions

Treatments	Stem			Leaf			Tuber			Total uptake		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
	T ₁ (RDF)	46.91	49.29	48.10	17.91	19.14	18.53	46.57	49.13	47.85	111.39	117.56
T ₂ (RDF+FYM)	48.20	61.60	54.90	20.68	23.23	21.96	52.80	56.55	54.68	121.68	141.38	131.53
T ₃ (RDF+FYM+AZOS)	50.64	68.77	59.71	22.85	25.79	24.32	68.78	73.66	71.22	142.27	168.22	155.25
T ₄ (1/3 RDF+FYM+AZOS)	49.65	63.71	56.68	21.09	24.01	22.55	65.27	60.61	62.94	136.01	148.33	142.17
T ₅ (1/2 RDF+FYM+AZOS)	47.32	60.95	54.14	20.24	21.97	21.11	50.31	53.88	52.10	117.87	136.80	127.34
T ₆ (RDF+VC)	51.12	68.54	59.83	24.45	25.54	25.00	65.58	70.24	67.91	141.15	164.32	152.74
T ₇ (RDF+VC+AZOS)	53.17	71.60	62.39	26.98	28.97	27.98	80.39	86.08	83.24	160.54	186.65	173.60
T ₈ (1/3 RDF+VC+AZOS)	51.86	69.82	60.84	25.56	27.80	26.68	79.64	85.29	82.47	157.06	182.91	169.99
T ₉ (1/2 RDF+VC+AZOS)	50.17	67.95	59.06	24.46	23.15	23.81	64.05	68.59	66.32	138.68	159.69	149.19
T ₁₀ (RDF+GM)	45.65	56.68	51.17	17.96	21.36	19.66	50.99	52.08	51.54	114.60	130.12	122.36
T ₁₁ (RDF+GM+AZOS)	48.76	61.27	55.02	18.92	22.78	20.85	58.40	65.52	61.96	126.08	149.57	137.83
T ₁₂ (1/3 RDF+GM+AZOS)	47.21	50.76	48.99	17.54	19.81	18.68	48.15	50.55	49.35	112.90	121.12	117.01
T ₁₃ (1/2 RDF+GM+AZOS)	45.32	48.77	47.05	16.98	19.05	18.02	45.29	48.50	46.90	107.59	116.32	111.96
General Mean	48.92	61.52		21.20	23.28		59.71	63.13		129.83	147.92	
S.E.m	0.88	1.02		1.37	1.51		3.46	4.18		5.35	7.32	
C.D (0.05)	2.57	2.98		4.01	4.42		10.12	12.22		15.64	21.40	

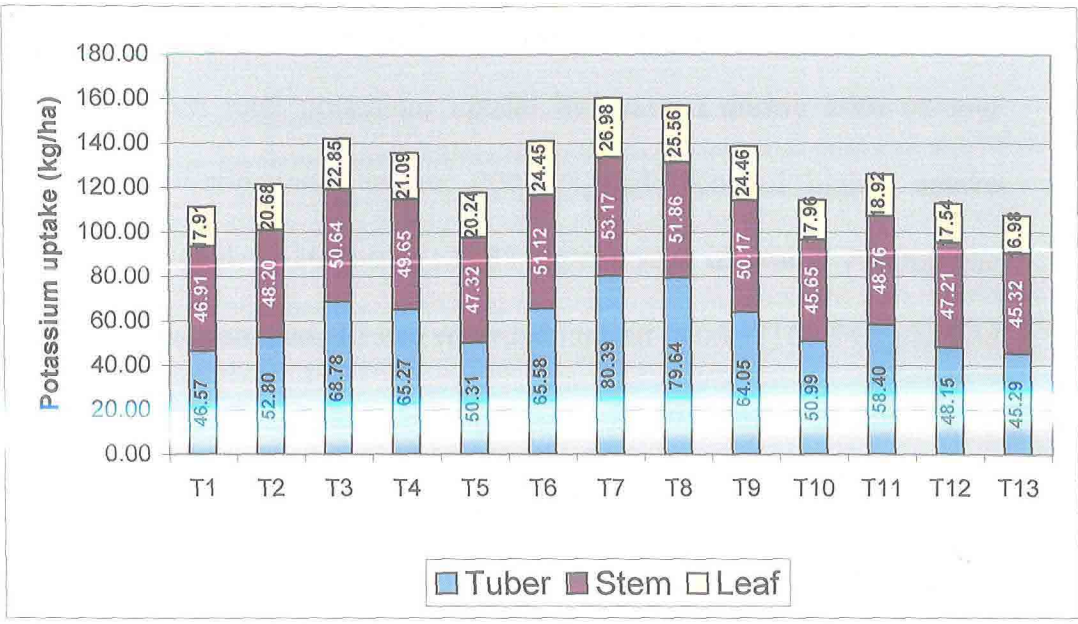
2003-04 years of study. Further, T3 (50.64 kg/ha), T6 (51.12 kg/ha) and T8 (51.86 kg/ha) during 2002-03; and T3 (68.77 kg/ha) and T8 (69.82 kg/ha) during 2003-04 had recorded potassium uptake on a par with T7.

4.2.17.2 Leaf

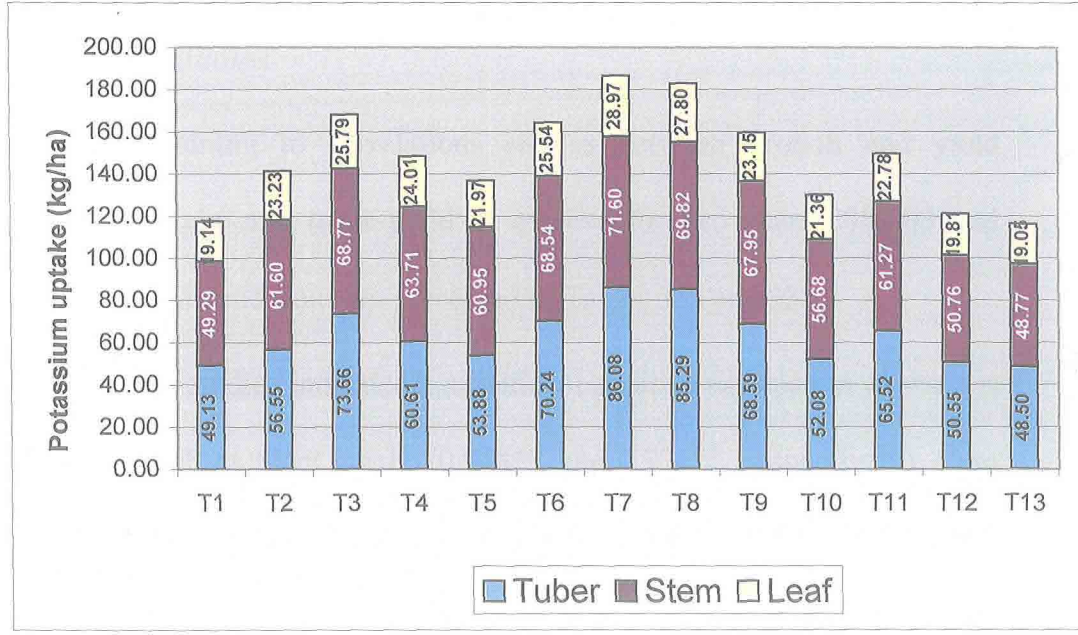
The significant influence of INM treatments studied in the present investigation was noticed on potassium uptake by cassava leaf during both 2002-03 and 2003-04 years of study. Potassium uptake by cassava leaf was observed to be higher during 2003-04 (23.28 kg/ha), compared to 2002-03 (21.20 kg/ha). Among the treatments, T7 had recorded highest potassium uptake (26.98 and 28.97 kg/ha, respectively), while T13 treatment had recorded lowest uptake (16.98 and 19.05 kg/ha, respectively) during 2002-03 and 2003-04 years of investigation. Further, the treatments, T6 (24.45 kg/ha), T8 (25.56 kg/ha) and T9 (24.46 kg/ha) during 2002-03; and T3 (25.79 kg/ha), T6 (25.54 kg/ha) and T8 (27.80 kg/ha) during 2003-04 had recorded potassium uptake on a par with T7 treatment.

4.2.17.3 Tuber

The different INM treatments studied had recorded a significant influence on potassium uptake by cassava tuber during different years of study. Higher potassium uptake by cassava tuber was observed during 2003-04 (63.13 kg/ha), compared to 2002-03 (59.71 kg/ha). Among the treatments, T7 had recorded highest uptake (80.39 kg/ha and 86.08 kg/ha, respectively), while T13 had recorded lowest uptake (45.29 kg/ha and 48.50 kg/ha, respectively) during both 2002-03 and 2003-04 years of study. Further, T8 during 2002-03 (79.64 kg/ha) and during 2003-04 (85.29 kg/ha) had recorded potassium uptake on a par with T7 treatment.



2002-03



2003-04

Fig. 16. Potassium uptake (kg/ha) in cassava as influenced by integrated nutrient management under irrigated conditions

4.2.17.4 Total

INM treatments studied in the present investigation had recorded a significant influence on total potassium uptake by cassava during 2002-03 and 2003-04 years of investigation. Further, 2003-04 had recorded higher uptake (147.92 kg/ha), compared to 2002-03 (129.83 kg/ha) year of study. Among the different INM treatments studied, T7 had recorded highest uptake (160.54 kg/ha and 186.65 kg/ha, respectively), while T13 had recorded lowest uptake (107.59 kg/ha and 116.32 kg/ha, respectively) during both 2002-03 and 2003-04. Further, the treatments, T8 (157.06 kg/ha) during 2002-03; and T3 (168.22 kg/ha) and T8 (182.91 kg/ha) during 2003-04 had recorded total potassium uptake on a par with T7 treatment.

4.2.18 Correlation studies

The data pertaining to correlations studies between growth and yield attributes, nutrient uptake and tuber yield of cassava for two years 2002-03 and 2003-04 under irrigated conditions are presented in Tables 33a and 33b.

The correlation studies indicated a significant positive association of various growth parameters such as plant height (0.944** and 0.936**, respectively), stem girth (0.565* and 0.882**, respectively), leaves per plant (0.888** and 0.913**, respectively), leaf area index (0.878* and 0.712**, respectively), total dry matter (0.908** and 0.903**, respectively), and growth analysis parameters like CGR (0.875** and 0.860**, respectively), and NAR (0.843** and 0.814**, respectively), and yield attributes like tubers per plant (0.935** and 0.943**, respectively), tuber length (0.921** and 0.958*, respectively), tuber girth (0.939** and 0.876**, respectively),

Table33a : Correlation matrix between growth and yield attributes, nutrient uptake and yield of cassava under irrigated conditions during 2002-03

	Plant height	Stem girth	Leaves plant ⁻¹	Leaf area index	Total dry matter	CGR	NAR	Tubers plant ⁻¹	Tuber length	Tuber diameter	N Uptake	P Uptake	K Uptake	Yield ha ⁻¹
Plant height	1.000	0.626*	0.887**	0.877**	0.881**	0.831**	0.765**	0.949**	0.957**	0.928**	0.810**	0.535*	0.727**	0.944**
Stem girth		1.000	0.558*	0.508	0.546	0.502	0.412	0.653*	0.731**	0.471	0.847**	0.658*	0.223	0.565*
Leaves plant ⁻¹			1.000	0.849**	0.794**	0.737**	0.658*	0.915**	0.843**	0.912**	0.797**	0.585*	0.655*	0.888**
Leaf area index				1.000	0.917**	0.918**	0.865**	0.842**	0.837**	0.791**	0.597*	0.387	0.790**	0.878**
Total dry matter					1.000	0.971**	0.960**	0.907**	0.877**	0.805**	0.549	0.575*	0.832**	0.908**
CGR						1.000	0.981**	0.822**	0.815**	0.755**	0.662*	0.593*	0.855**	0.875**
NAR							1.000	0.774**	0.757**	0.700**	0.660*	0.580*	0.853**	0.843**
Tubers plant ⁻¹								1.000	0.956**	0.918**	0.659*	0.399	0.700**	0.935**
Tuber length									1.000	0.882**	0.479	0.356	0.648*	0.921**
Tuber girth										1.000	0.601*	0.281	0.763**	0.939**
N Uptake											1.000	0.320**	0.434	0.571*
P Uptake												1.000	0.261	0.530*
K Uptake													1.000	0.835**
Yield ha ⁻¹														1.000

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 33b : Correlation matrix between growth and yield attributes, nutrient uptake and yield of cassava under irrigated conditions during 2003-04

	Plant height	Stem girth	Leaves plant ⁻¹	Leaf area index	Total dry matter	CGR	NAR	Tubers plant ⁻¹	Tuber length	Tuber diameter	N Uptake	P Uptake	K Uptake	Yield ha ⁻¹
Plant height	1.000	0.936**	0.953**	0.708**	0.909**	0.899**	0.845**	0.956**	0.968**	0.854**	0.868**	0.614*	0.673*	0.935**
Stem girth		1.000	0.960**	0.636*	0.952**	0.922**	0.909**	0.919**	0.952**	0.865**	0.889**	0.765**	0.609*	0.882**
Leaves plant ⁻¹			1.000	0.754**	0.953**	0.949**	0.901**	0.889**	0.943**	0.905**	0.834**	0.686**	0.642*	0.913**
Leaf area index				1.000	0.698**	0.761**	0.624*	0.555*	0.640*	0.620*	0.422	0.389	0.565*	0.712**
Total dry matter					1.000	0.971**	0.967**	0.870**	0.933**	0.861**	0.778**	0.800**	0.727**	0.903**
CGR						1.000	0.976**	0.810**	0.881**	0.770**	0.724**	0.718**	0.644*	0.860**
NAR							1.000	0.789**	0.853**	0.732**	0.710**	0.815**	0.606*	0.814**
Tubers plant ⁻¹								1.000	0.975**	0.862**	0.868**	0.648*	0.654*	0.941**
Tuber length									1.000	0.905**	0.840**	0.722**	0.700**	0.958**
Tuber girth										1.000	0.789**	0.668*	0.677*	0.876**
N Uptake											1.000	0.657*	0.520	0.731**
P Uptake												1.000	0.469	0.584*
K Uptake													1.000	0.763**
Yield ha ⁻¹														1.000

* Significant at the 0.05 level

** Significant at the 0.01 level

respectively), and nutrient uptake namely N (0.571* and 0.731**, respectively), P uptake (0.584**), and K uptake ((0.835** and 0.763**, respectively) during both the years of study, except P uptake during 2002-03 with tuber yield of cassava.

4.2.19 Cost of cultivation

The cost of cultivation, gross and net returns in addition to benefit : cost ratio of different INM treatments studied in the present investigation are presented in Table 34 and Figs.17 and 18.

4.2.19.1 Total expenditure

The total expenditure was observed to range from Rs 11513/- (T13) to Rs 30601/- (T7) during 2002-03 and Rs 10420/- (T13) to Rs 28414/- (T7) during 2003-04 years of investigation (Table 34). In general, treatments involving vermicompost component recorded higher expenditure followed by farm yard manure, compared to the treatments involving green manure component during both the years of study.

4.2.19.2 Gross returns

Gross returns for different INM treatments in the present investigation ranged from Rs 39193/- (T1) to Rs 63308/- (T7) during 2002-03 and from Rs 34416/- (T1) to Rs 50024/- (T7) during 2003-04. The returns were in general observed to be higher for treatments involving vermicompost component, compared to farm yard manure and green manure components.

Table 34 : Cost of cultivation of integrated nutrient management in cassava under irrigated conditions

Treatments	Total expenditure (Rs/-)			Gross returns (Rs/-)			Net returns (Rs/-)			Benefit : cost ratio		
	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean	02-03	03-04	Mean
T ₁ (RDF)	20526	18339	19433	39193	34416	36804	18667	16077	17372	1.91	1.88	1.89
T ₂ (RDF+FYM)	23026	20839	21933	48153	43667	45910	25127	22828	23977	2.09	2.10	2.09
T ₃ (RDF+FYM+AZOS)	23101	20914	22008	53770	47273	50522	30669	26359	28514	2.33	2.26	2.29
T ₄ (1/3 RDF+FYM+AZOS)	16259	14801	15530	52055	46273	49164	35796	31472	33634	3.20	3.13	3.16
T ₅ (1/2 RDF+FYM+AZOS)	12838	11745	12291	45825	40140	42983	32987	28396	30691	3.57	3.42	3.49
T ₆ (RDF+VC)	30526	28339	29433	57340	46970	52155	26814	18631	22723	1.88	1.66	1.77
T ₇ (RDF+VC+AZOS)	30601	28414	29508	63308	50024	56666	32707	21610	27158	2.07	1.76	1.91
T ₈ (1/3 RDF+VC+AZOS)	23759	22301	23030	59160	48800	53980	35401	26499	30950	2.49	2.19	2.34
T ₉ (1/2 RDF+VC+AZOS)	20338	19245	19791	55888	44720	50304	35550	25476	30513	2.75	2.32	2.54
T ₁₀ (RDF+GM)	21701	19514	20608	46350	38259	42304	24649	18745	21697	2.14	1.96	2.05
T ₁₁ (RDF+GM+AZOS)	21776	19589	20683	49903	42575	46239	28127	22986	25556	2.29	2.17	2.23
T ₁₂ (1/3 RDF+GM+AZOS)	14934	13476	14205	48888	40851	44869	33954	27375	30664	3.27	3.03	3.15
T ₁₃ (1/2 RDF+GM+AZOS)	11513	10420	10966	42675	36192	39434	31162	25773	28467	3.71	3.47	3.59

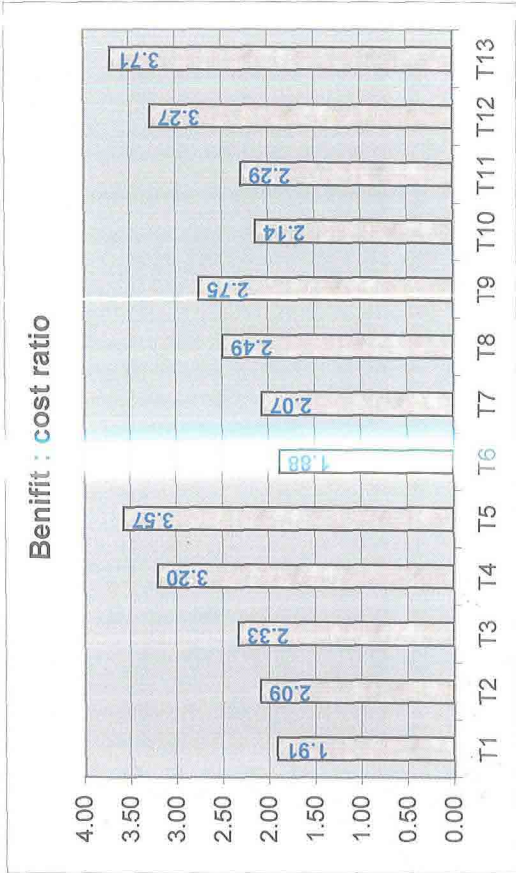
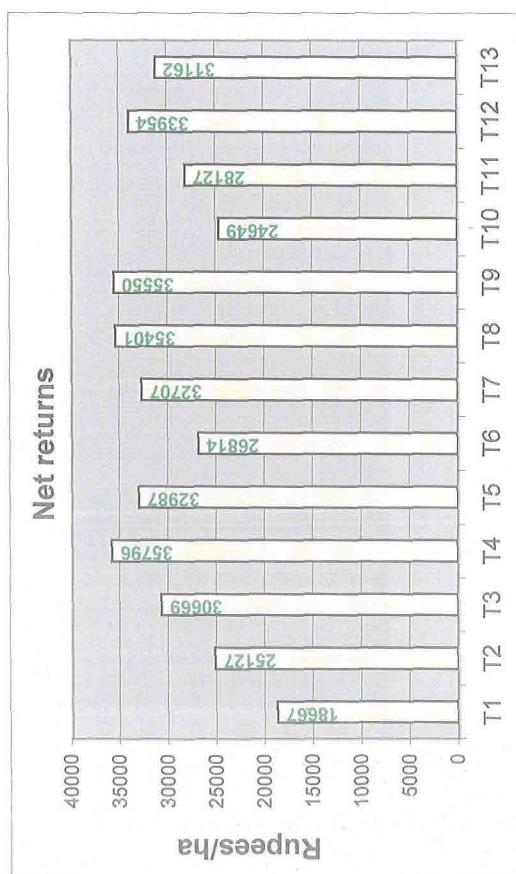
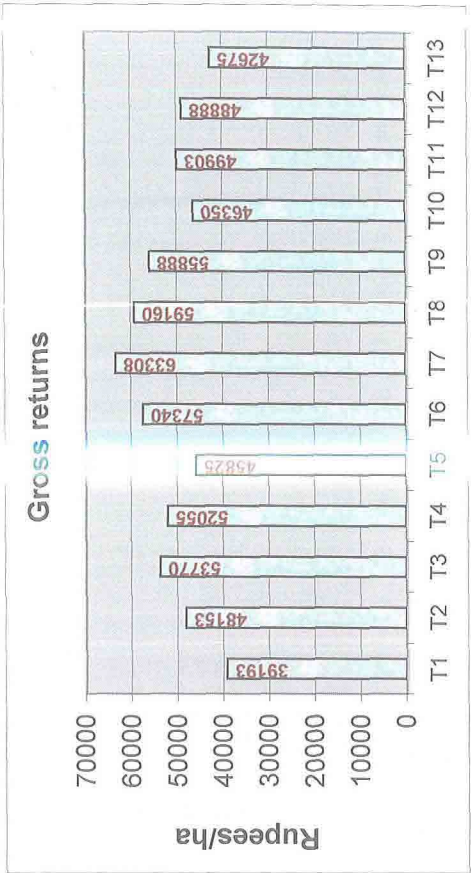
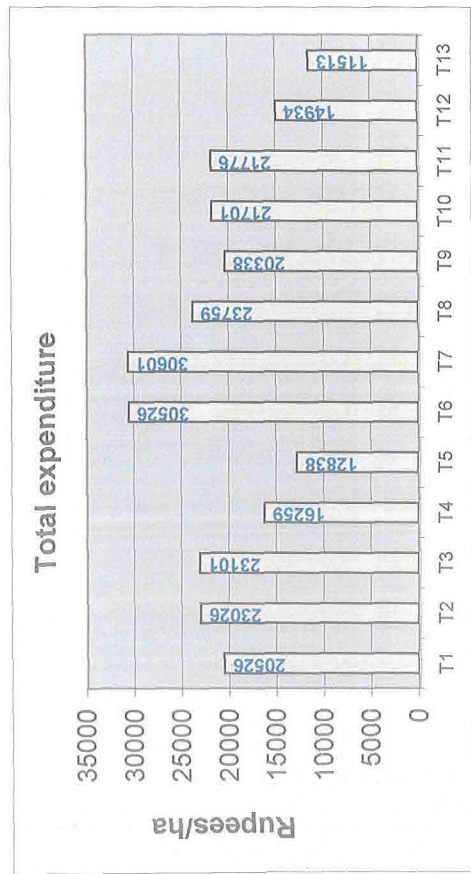


Fig. 17. Cost of cultivation of different integrated nutrient management treatments during 2002-03 under irrigated conditions

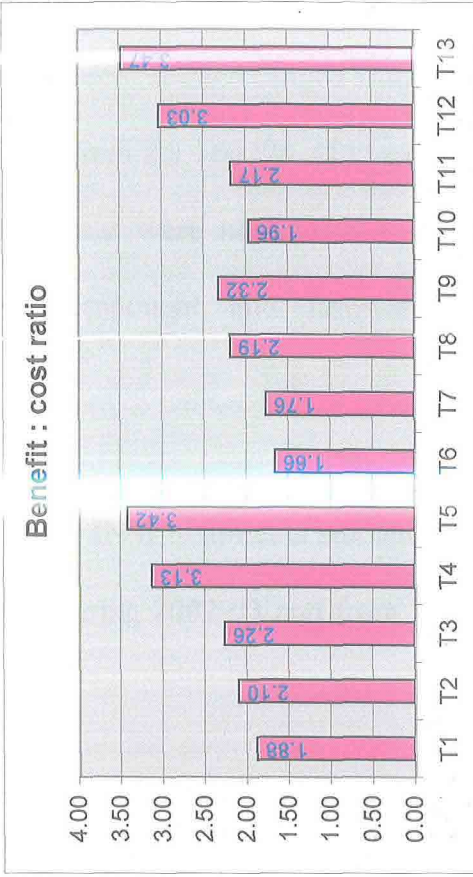
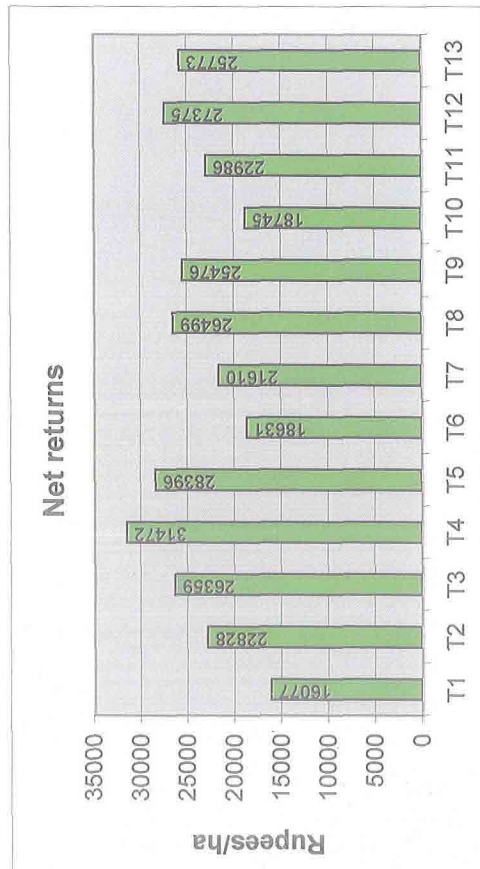
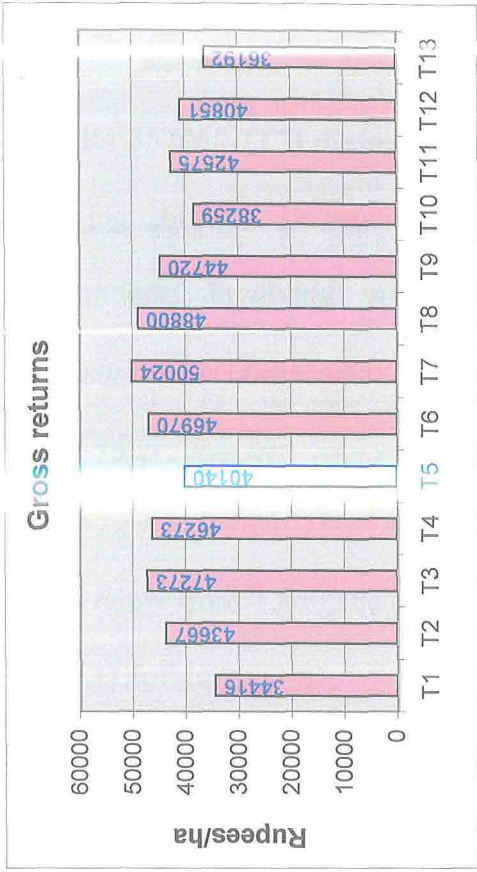
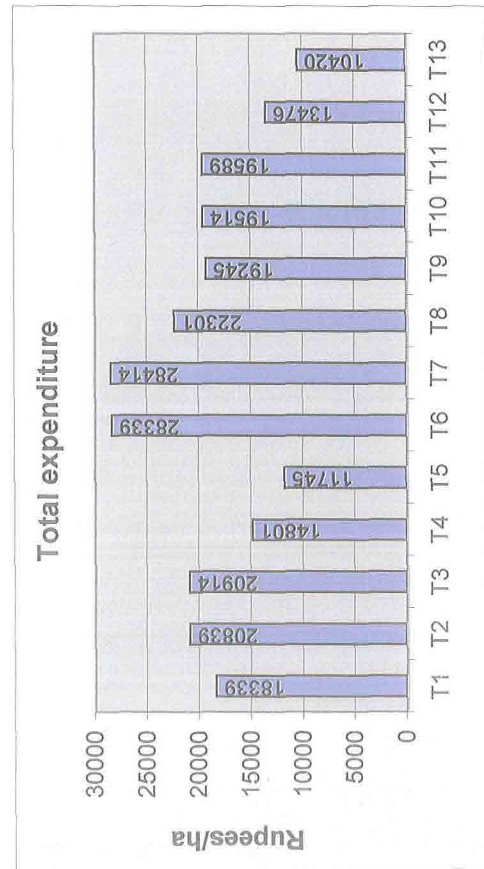


Fig. 18. Cost of cultivation of different integrated nutrient management treatments during 2003-04 under irrigated conditions

4.2.19.3 Net returns

Net returns of different INM treatments studied ranged from Rs 18667/- (T1) to Rs 35796/- (T7) during 2002-03 and from Rs 16077/- (T1) to Rs 31472/- (T4) during 2003-04. In general, the net returns were noticed to be higher for INM treatments involving vermicompost component and farmyard manure with *Azospirillum* components.

4.2.19.4 Benefit : cost ratio

The benefit : cost ratio of different INM treatments studied was observed in the range from 1.88 (T6) to 3.71 (T13) during 2002-03 and from 1.66 (T6) to 3.47 (T13) during 2003-04.

Chapter V

Discussion

CHAPTER V

DISCUSSION

Cassava is an important industrial crop of Andhra Pradesh. However, it is mostly grown on relatively poor soils under rainfed conditions to a large extent and under irrigated conditions to a lesser extent, wherever irrigation facilities are available in the upland tracts of East Godavari district of the State. Traditionally, the crop is grown with the application of organic manures only (Mohankumar *et al.*, 2000) and the application of inorganic fertilizers to the crop is considered a luxury (Howeler, 1980). However, cassava is a heavy feeder and requires good amounts of nitrogen, phosphorus and potash for realization of high yields (Mitra *et al.*, 1990). Nayer (1994) also reported that continuous cassava cropping without adequate soil fertility management can result in severe reduction in growth and yield of succeeding crops in addition to deterioration of soil fertility.

Integrated use of organic manures, bio-fertilizers and inorganic fertilizers in cassava nutrition can help to maintain optimum crop yields and long term sustainable productivity of the crop. In this context, the present investigation on nutrient management in cassava was undertaken with various doses of recommended inorganic fertilizers and locally available organic manures along with the bio-fertilizer, *Azospirillum* for the rainfed and irrigated cropping situations of cassava during 2002-03 and 2003-04. The results pertaining to growth, development, yield, quality, nutrient uptake and cost of cassava cultivation obtained in the present studies are discussed in detail in this chapter.

5.1 GROWTH CHARACTERS

Growth is an irreversible increase in size of plants and it is affected by external inputs such as nutrients. The growth characters like plant height, stem girth, number of nodes and leaves per plant in addition to leaf area and leaf area index contribute for economic yield of the crop and the results on effect of different integrated nutrient management treatments on these growth parameters during 2002-03 and 2003-04, under rainfed and irrigated situations of cassava cultivation are discussed hereunder.

The growth characters were in general observed to increase rapidly from 60 to 150 DAP, the grand growth period involving high physiological activity and thereafter, the increase was marginal up to harvest during both years of investigation under both rain fed (Tables 1-6) and irrigated situations (Tables 18-23). However, the number of leaves, leaf area per plant and leaf area index (Tables 4-6 and 21-23) showed a decline at later stages of crop growth (180 and 210 DAP) due to the senescence of older leaves. The reduced rate of increase for plant height, stem girth, number of nodes and leaves per plant in addition to leaf area and leaf area index beyond 120 DAP (Tables 1-6 and 18-23) may be attributed to the rapid increase in root growth and also because of diversion of more photosynthates from source (leaves) to sink (root) which is a common biological phenomenon in almost all root crops (Ravindrababu, 1999). Further, lower plant height, stem girth, number of nodes and leaves per plant in addition to leaf area per plant and leaf area index were in general observed at all the crop growth stages during 2002-03, compared to 2003-04 under rainfed conditions (Tables 1-6) due to the occurrence of frequent

dryspells resulting from low and erratic rainfall (Appendix I) during the period (2002-03).

In the present investigation, application of organic manures in conjunction with bio-fertilizer and inorganic fertilizers at different levels (T2 – T13) exerted a significant influence on plant height, number of nodes and leaves per plant at 60, 90, 120, 150, 180 and 210 DAP; stem girth at 120, 150, 180 and 210 DAP; leaf area and leaf area index at 30, 60, 90, 120, 150, 180 and 210 DAP, under both rainfed (Tables 1-6) and irrigated (Tables 18-23) conditions during both 2002-03 and 2003-04.

The application of recommended NPK fertilizer dose along with vermicompost and *Azospirillum* (T₇) was observed to result in highest plant height, stem girth, number of nodes and leaves per plant in addition to leaf area and leaf area index at all the growth stages studied during both the years of investigation under rainfed (Tables 1-6) and irrigated conditions (Tables 18-23), except during 2002-03 at 30 DAP for number of leaves per plant; at 150 DAP during 2002-03 for leaf area per plant and leaf area index under rainfed conditions. This may be attributed to the fact that vermicompost with its richness in both macro and micro nutrients besides having certain growth promoters, humus farming microbes and sustained availability of nutrients throughout the crop growth period by the nitrogen fixers in it might have helped in increasing various growth parameters by exerting its synergistic effect with inorganic and bio-fertilizers (Bano *et al.*, 1987). This could also be attributed to accelerated cell division and elongation as well as greater

chlorophyll synthesis and higher metabolic activity as suggested by Nazeerahmed and Tanki (1988).

The production of growth promoting substances and vitamins by vermicompost and bio-fertilizer and their favorable influences in increasing the growth attributes had also been reported earlier by several workers (Ravingnanam and Gunathilagaraj, 1996; Kamalakarreddy, 1998 and Ramachandrareddy, 1998), similar to the findings of the present investigation. Further, the promotive effect of *Azospirillum* on plant height and other growth characters of cassava was also reported earlier by Sucheta (1989). Govindan and Purushothaman (1984) ascribed the increase in growth characters due to *Azospirillum* to its role in 'N' fixation and also the production of phyto-hormones like substances. Further, the increase in growth characters with the INM treatment (T7) may also be attributed to the increased uptake of nutrients such as N (Table 14 and 31), which was made available by the activity of inoculated bacteria (Okon and Kapulnik, 1986). The absorbed nitrogen combining with carbohydrates synthesized by leaves through increased photosynthetic activity might have led to the formation of amino acids and proteins resulting in the build up of new tissues and the consequent increase in growth characters (Childers, 1966).

Application of vermicompost in conjunction with recommended dose of inorganics (T6) and at different levels of inorganics and bio-fertilizer, *Azospirillum* (T8 and T9) had also resulted in significantly higher growth attributes namely plant height, stem girth, number of nodes and leaves per plant in addition to leaf area per plant and leaf area index at most of the growth stages during the two years of

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investigation under both rainfed (Table 1–6) and irrigated (Table 18–23) conditions, compared to application of recommended dose of inorganic fertilizers (T1). This may be attributed to (i) the higher supply of nutrients by vermicompost containing higher amounts of total and available nitrogen, organic matter, total exchangeable calcium, magnesium, potassium and available phosphorus (Joshi and Kelkar, 1952), (ii) the plant growth promoters such as auxins, cytokinins and group ‘B’ vitamins (Nielson, 1965; Krishnamoorthy and Vajranabhaiah, 1986) and (iii) upon its decomposition in soil besides its effect on increasing the efficiency of inorganic fertilizers (Kale *et al.*, 1992). Gunjal and Nikam (1992) also attributed the favorable effects of vermicompost to increased availability of nutrients, organic carbon content and water holding capacity. These observations were also supported from results of the nutrient uptake studies in the present investigation, where in the application of vermicompost had significantly increased the uptake of N, P and K nutrients under both rainfed (Tables 14-16) and irrigated (Tables 31-33) conditions during both the years of investigation.

Application of FYM and green manure in combination with recommended inorganic fertilizers (T2 and T10), and with *Azospirillum* in conjunction with recommended (T3 and T11) / reduced levels of inorganic fertilizers (T4, T5, T12 and T13) had however, resulted in growth attributes on par with the application of recommended fertilizer dose (T1) in the initial stages 60 DAP under rainfed conditions, while significantly higher growth attributes were observed for the treatments at later growth stages (120, 150, 180, and 210 DAP). This may be attributed to the fact that initially there was rapid availability of nutrients, especially

nitrogen through inorganics and vermicompost, compared with that of FYM and green manure due to slow release of nitrogen in the organics owing to their relatively wider C: N ratio (Bhandari *et al.*, 1992) and also due to in situ incorporation of green manure at 45 days after sowing.

In contrast, significantly higher growth attributes were recorded for application of FYM in conjunction with different levels of recommended dose of inorganic fertilizers and bio-fertilizers under irrigated conditions (T2, T3, T4 and T5) even in the initial stages (60 DAP) compared to application of recommended dose of inorganic fertilizers (T1), unlike rainfed conditions probably due to faster decomposition and increased availability of nutrients even from the early stages of crop growth under irrigated conditions (Maskina *et al.*, 1988). The growth attributes recorded for green manural treatments in conjunction with different levels of recommended dose of inorganic fertilizers and bio-fertilizer were however, non-significant compared to application of recommended dose of inorganic fertilizers at 60 DAP under both rainfed and irrigated conditions, unlike with FYM component, probably due to in situ incorporation of green manure at 45 days after planting of cassava under both rainfed and irrigated conditions.

The increased growth attributes observed with FYM (T2, T3, T4 and T5) and green manure (T10, T11, T12 and T13) treatments at later growth stages, compared to the use of recommended inorganics alone (T1) may be attributed to the improvement in soil physical properties (Maskina *et al.*, 1988); slow release and availability of nutrients for absorption by the plants for longer periods with the organics, compared to the immediate availability of the nutrients and subsequent loss through

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evaporation and leaching in the inorganics at later stages, as reported by Sharma and Mitra (1990). Further, Amanullahkhan (1997) had also reported an increase in the growth attributes of cassava with the application of FYM along with inorganic fertilizers, similar to the findings of the present investigation.

The application of 2/3rd recommended dose of inorganic fertilizers along with vermicompost and *Azospirillum* (T8) was also observed to in general result in growth attributes on par with recommended dose of inorganic fertilizer applied in conjunction with vermicompost and *Azospirillum* (T7) during both years of investigation and under both rainfed (Tables 1-6) and irrigated (Tables 18-23) situations, indicating a scope for reduction in inorganic fertilizers by about 33 per cent, thereby resulting in a reduction in the total cost of cassava cultivation under both rainfed and irrigated situations as also evidenced by the cost of cultivation results of the present investigation (Tables 17 and 34, respectively).

On comparison of the growth characteristics of cassava the responses to the treatments imposed to the present investigation between rainfed and irrigated situation, the crop has shown better growth under irrigated situation. It could be attributed to constant maintenance of soil moisture at optimum level without any moisture stress resulted in better nutrient uptake.

5.2 DRY MATTER PRODUCTION AND GROWTH ANALYSIS

Dry matter production of cassava was observed to increase progressively with advancement in crop age up to harvest, under both rainfed and irrigated conditions during both the years of investigation. The increase in dry matter production is attributed to the cumulative effect of progressive increase in the

growth attributes, viz., plant height, stem girth and number of nodes per plant with advancement in crop age up to harvest; and number of leaves and leaf area per plant up to 150 DAP. Similar results have been reported earlier in cassava (Ammanullahkhan, 1997) and sweet potato (Nedunchezian, 2002). Further, the rate of dry matter production was observed to be relatively high during 90-120 DAP and 120-150 DAP, compared to other growth stages under both rainfed and irrigated conditions during both the years of investigation. due to the production of maximum number of photosynthetically active leaves (Tables 4 and 21) and leaf area (Tables 5 and 22) in addition to leaf area index (Tables 6 and 23) resulting in high NAR (Tables 10 and 27) leading to the production of more photosynthates and thereby a rapid increase of the growth characters, as also evidenced by high CGR at these growth stages (Tables 9 and 26). The above findings are in conformity with the reports of Keating *et al.* (1982) and Ammanullahkhan (1997) in cassava; and Neeraja (1998) and Jayatilake (2002) in onion. Further, the dry matter accumulation in cassava largely occurs in economically important tuberous roots from tuber initiation stage, beginning from 30-45 DAP, while the stem and leaves are still growing. The pattern of translocation of assimilates from the leaves determines, how dry matter is partitioned and what fraction of the product of photosynthesis is laid down in the economically important tuberous roots. An analysis of dry matter partitioning in cassava at harvest in the present investigation revealed translocation of 54-55 per cent of the photosynthates to the tuberous roots, 25-28 per cent to the stem and retention of the rest (18-20 %) in the leaves.

The growth analysis parameters namely, crop growth rate (CGR), the product of leaf area index and net assimilation rate are indicative of dry matter production per unit time (Watson, 1958); and net assimilation rate (NAR), essentially an estimate of canopy photosynthesis per unit leaf area and a measure of photosynthetic efficiency also increased progressively with advancement in the crop age. Further, maximum CGR and NAR were recorded at 120-150 DAP and thereafter both CGR and NAR declined. The increase in CGR and NAR up to 120-150 DAP is attributed to the increase in growth attributes namely, plant height, stem girth, number of nodes and leaves per plant in addition to leaf area and leaf area index (Tables 1-6 and 18-23) with an increase in crop age upon 150 DAP, while the decrease thereafter was primarily due to a reduction in the leaf number, due to abscission of older leaves, leading to decreased leaf area per plant and LAI (Tables 4-6 and 21-23). Keating *et al.* (1982) also reported CGR to be highly associated with LAI, similar to the findings of the present investigation.

The application of organic manures in combination with biofertilizer and inorganic fertilizers at different levels was also observed to exert a significant influence on dry matter partitioning at harvest (Table 8 and 25), dry matter production at the different growth stages studied and shoot/root ratio, while the effect was observed to be significant only at 90-120 DAP and 120-150 DAP for the growth analysis parameters namely, CGR and NAR, due to the high rate of dry matter accumulation at these growth stages, compared to the marginal rate of dry matter accumulation at other growth stages, under both rainfed (Tables 7-11) and irrigated (Tables 24-28) conditions, during both the years of investigation.

Among the different INM treatments studied, application of recommended NPK fertilizer dose along with vermicompost and *Azospirillum* (T7) was observed to result in maximum dry matter production in stem, leaf and tuber at harvest and also at all the growth stages studied, in addition to maximum CGR and NAR at 90-120 DAP and 120-150 DAP during both the years of investigation under both rainfed and irrigated conditions, except CGR at 120-150 DAP under rainfed conditions, as a result of the synergistic interaction between vermicompost biofertilizer and inorganic fertilizers leading to maximum stature of majority growth attributes at most of the growth stages studied (Tables 7 and 24). The growth attributes on application of biofertilizer in conjunction with vermicompost and inorganic fertilizers (T7) were enhanced by the production of bioactive substances having similar effect as that of growth regulators besides nitrogen fixation through bacterial fertilizers leading to greater dry matter production. Similar findings were reported by Amrithalingam (1988), Parvatham and Vijayan (1989) and Subbiah (1994). Further, the treatment had also recorded minimum shoot/root ratio among the different INM treatments studied, under both rainfed and irrigated conditions during both the years of investigation.

Application of vermicompost in conjunction with recommended dose of inorganic fertilizers (T6) and different levels of inorganics and biofertilizer (T8 and T9) had also resulted in significantly greater dry matter production in general, compared to application of inorganics alone (T1) in stem, leaf and tuber at harvest and also at the various crop growth stages studied during the both the years of investigation under rainfed and irrigated conditions. This may be attributed to the

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favorable influence of vermicompost on the growth attributes as a result of greater availability of nutrients (Gunjal and Nikam, 1992). Similar results were reported earlier in onion (Jayathilake, 2002). Further, the application of vermicompost and biofertilizer in conjunction with $2/3^{\text{rd}}$ (T8) and $1/2$ dose (T9) of inorganic fertilizers was also observed to in general result in dry matter production on par with the application of vermicompost and biofertilizer in conjunction with full dose of inorganics (T7), indicating a scope for saving of inorganic fertilizers with the conjoint application of vermicompost, biofertilizer and inorganics. Further, the treatments had also recorded significantly lower shoot/root ratio, compared to the application of inorganics alone, under both rainfed and irrigated conditions during both the years of investigation.

The application of FYM in combination with recommended inorganic fertilizers (T2) and with *Azospirillum* in conjunction with recommended (T3) and reduced levels of inorganic fertilizers (T4 and T5) had also in general recorded a total dry matter production significantly higher to application of recommended inorganic fertilizers only (T1) under both rainfed and irrigated conditions during both the years of investigation. Similar results were reported by Badrova and Gavrilova (1973) in potato, wherein the application of FYM along with N, P and K fertilizers had resulted in higher dry matter production, compared to the single application of N, P and K. Further, Mohankumar *et al.* (1976) reported the effect of inorganic fertilizers and FYM to be additive on cassava dry matter production. The studies of Kabeerathumma *et al.* (1988) also revealed maximum cassava dry matter production in experimental plots receiving continuous application of FYM and NPK. Similar

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beneficial effects of FYM application in conjunction with inorganic fertilizers was reported in garden pea by Ramachandrareddy *et al.* (1998). Further, the above treatments, with the exception of T5 under irrigated conditions had also recorded significantly lower shoot/root ratio, compared to the application of inorganics alone (T1), under both rainfed and irrigated conditions during both the years of investigation.

In the present investigation, the application of 2/3rd and ½ dose of recommended inorganic fertilizers in conjunction with FYM and biofertilizer *Azospirillum* (T4 and T5) had also resulted in dry matter production on par with the application of full recommended dose of inorganic fertilizers in conjunction with FYM (T2) and *Azospirillum* (T3) under both rainfed and irrigated conditions, during both the years of investigation, indicating a scope for saving of inorganic fertilizers. Vasudevan *et al.* (2003) also reported a reduction in the dose of inorganic fertilizers with the application of biofertilizer along with NPK inorganic fertilizers due to effective utilization of the applied inorganic nutrients. The studies of Nayer *et al.* (2003) on the response of cassava to *Azospirillum* in combination with chemical fertilizers and FYM had also revealed that the combined use of biofertilizers with recommended dose of FYM, K, 50% N and P had resulted in cassava dry matter yields on par with full recommended dose of FYM and NPK suggesting the possibility of reducing inorganic N and P dosage in cassava production, similar to the findings of the present investigation.

The application of green manure in combination with recommended inorganic fertilizers (T10); and with *Azospirillum* in conjunction with full

recommended (T11) and reduced levels of inorganic fertilizers (T12 and T13) had also recorded significantly higher dry matter production to application of inorganic fertilizers alone (T1) at later stages of crop growth namely, 150 and 180 DAP under both rainfed and irrigated conditions during both the years of investigation. The dry matter production at early crop growth stages namely, 30, 60, 90 and 120 DAP was however, in general observed to be on par with the dry matter production recorded with the application of inorganics alone (T1). This is attributed to the in-situ incorporation of green manure at 45 days after sowing resulting in availability of the nutrients only at later growth stages. The above treatments had also in general recorded lower shoot/root ratio, compared to the application of inorganics alone (T1), under both rainfed and irrigated conditions during both the years of investigation.

The application of vermicompost, FYM and green manure in combination with recommended dose of fertilizers (T2, T6 and T10, respectively) and with *Azospirillum* in conjunction with recommended (T3 and T11) and reduced levels of inorganic fertilizers (T4, T5, T8, T9, T12 and T13) had however, in general resulted in CGR and NAR on par with the application of recommended fertilizer dose (T1) at 90-120 DAP under rainfed conditions, while significantly higher CGR and NAR were observed for the treatments at 120-150 DAP. This may be attributed to the fact that there was rapid availability of nutrients especially 'N' through inorganics, compared with that of organics, due to slow release of nitrogen in the organics owing to their relatively wider C: N ratio (Bhandari *et al.*, 1992).

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Significantly higher CGR and NAR were however, recorded for the application of organics in conjunction with different levels of recommended dose of inorganic fertilizers and biofertilizers under irrigated conditions (T2 and T13) even at 90-120 DAP, compared to application of RDF (T1), unlike rainfed conditions probably due to the faster decomposition and increased availability of nutrients from the early stages of crop growth under irrigated conditions (Maskina *et al.*, 1988).

5.3 YIELD, YIELD ATTRIBUTES AND QUALITY

The realization of tuber yield in cassava depends on the amount of dry matter translocated to the sink. The ability of the sink, as indicated by the number and size of tubers to accept assimilates is considered a major factor leading to tuber yield. Yield of cassava relies on available solar radiation, photosynthetic capacity of the crop and duration of that capacity. Part of the photosynthates (stored as well as current) produced by the source (leaves) would be translocated for sink (tuberous root) development. The amount of photosynthates that come out from the source and the ability to accumulate in the sink determines the tuber yield.

The application of organic manures in conjunction with biofertilizer and inorganic fertilizers at different levels was observed to exert a significant influence on tuber yield and yield attributes under both rainfed (Table 12) and irrigated (Table 29) conditions during both the years of investigation, except tuber length under rainfed conditions. The tuber quality attributes studied in the present investigation also did not record any significant influence due to different INM treatments studied under both rainfed (Table 13) and irrigated (Table 30) conditions during both the years of investigation. The findings are in conformity with the

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reports of Ammanullahkhan (1997). He had reported similar non-significant effect of different INM treatments on cassava tuber quality attributes, namely starch and hydrocyanin content.

The application of recommended NPK fertilizer dose along with vermicompost and *Azospirillum* (T7) was observed to result in maximum number of tubers per plant, tuber length and diameter, tuber weight per plant and yield per hectare under both rainfed and irrigated conditions during both the years of investigation, due to maximum dry matter production, CGR and NAR recorded for the treatment as result of maximum stature of the different growth attributes studied in the present investigation. Ramanujam and Biradar (1987) had also reported significant positive correlation for tuber yield in cassava with dry matter production, CGR and NAR. Further, Ammanullahkhan (1997) reported a strong positive association of the growth attributes namely, plant height, leaf area index and dry matter production; and yield attributes namely, number of tubers per plant, tuber length and tuber girth with tuber yield of cassava, similar to the findings of the present investigation. The high yield recorded for the treatment may also be attributed to the synergistic interactions between vermicompost, biofertilizer and inorganic fertilizers leading to the production of growth promoting bioactive substances (Subbiah 1994) and improvement of soil physical conditions (Chauhan and Nanawathi, 1971; Maurya and Goswami, 1985) leading to greater tuber length and girth and thereby increased yields.

Application of vermicompost in conjunction with recommended dose of inorganic fertilizers (T6) and different levels of inorganics and biofertilizer

(T8 and T9) had also in general resulted in significantly higher yield and yield attributes, compared to application of inorganics alone (T1) under both rainfed and irrigated conditions during both the years of investigation. The findings are in conformity with the reports of Shinde *et al.* (1992) and Jayatilake (2002). The increase in yield with the integrated application of vermicompost either alone or in conjunction with biofertilizer coupled with the inorganic fertilizers may be attributed to the increased availability of nutrients resulting from the decomposition of vermicopost leading to accelerated synthesis of chlorophyll and amino acids (Devlin, 1973) and increased translocation of photosynthates from leaves to the tubers leading to increase in the number of tubers per plant, in addition to tuber length and girth (Singh *et al.*,1997) and thereby an increase in the yield.

The application of FYM in combination with *Azospirillum* in conjunction with recommended dose of inorganics (T3) had also recorded tuber weight per plant and yield per hectare significantly higher to application of recommended inorganic fertilizers only (T1) under both rainfed and irrigated conditions during both years of investigation. Similar beneficial effects of the integrated application of inorganics, FYM and *Azospirillum* were reported earlier by Jayatilake (2002) in onion. The application of FYM in combination with *Azospirillum* in conjunction with 2/3rd level of inorganic fertilizers (T4) had also resulted in tuber weight per plant and yield per hectare significantly higher to application of recommended inorganic fertilizers only (T1) under both rainfed and irrigated conditions during both years of investigation, indicating a scope for saving of the inorganic fertilizers under both rainfed and irrigated conditions. The biofertilizer applied along with NPK inorganic

fertilizers helped in the utilization of applied inorganic nutrients more efficiently thereby reducing the dose of inorganic fertilizers as explained by (Vasudevan *et al.*, 2003).

The application of FYM in conjunction with recommended dose of inorganics (T2) had also resulted in tuber weight per plant and yield per hectare significantly higher to that, compared with the application of inorganics only (T1) under irrigated conditions. Several workers had also reported similar higher tuber yields in potato (Badrova and Gavrilova, 1973; Mohankumar *et al.*, 1976; Mandal and Mazumdar, 1980), sweet potato (Ravindran and Balanambisan, 1987) and cassava (Kabeerthuma *et al.*, 1988) with the application of FYM and inorganic NPK fertilizers, compared to the single application of NPK fertilizers. Further, application of FYM in combination with *Azospirillum* in conjunction with $\frac{1}{2}$ level of inorganic fertilizers (T5) had also resulted in tuber weight per plant and yield per hectare significantly higher compared with the application of inorganics only (T1) and on par with the application of recommended inorganics and FYM (T2) under irrigated conditions, indicating a scope for saving of inorganic fertilizers by about 50 per cent under the irrigated conditions. Similar results were reported earlier by Nayer *et al.* (2003) in their studies on the response of cassava to *Azospirillum* in combination with chemical fertilizers and FYM. They had also reported that the conjoint use of biofertilizers with recommended dose of FYM, K, 50% N and P resulted in cassava tuber yields on par with full recommended dose of FYM and NPK suggesting a possibility for reducing of inorganic N and P dosage in cassava production. However, the above treatments (T2 and T4) had recorded tuber weight and yield per

hectare on par with the application of inorganics alone (T1) under rainfed conditions, probably due to unavailability of sufficient nutrients in these treatments under rainfed conditions.

The application of green manure in conjunction with *Azospirillum* and different levels of inorganic fertilizers (T10 to T13) had also in general recorded yield and yield attributes on par with the application of recommended inorganic fertilizers only (T1) under rainfed conditions during both the years of investigation, probably due to unavailability of sufficient nutrients in these treatments under rainfed conditions, resulting from the slow and delayed decomposition of organic material applied under restricted moisture conditions. In contrast, the treatments (T10 to T12) had recorded significantly higher yield and yield attributes, compared to the application of recommended inorganic fertilizers only (T1) under irrigated conditions during both the years of investigation. The findings are in conformity with the reports of Chatterjee *et al.* (1979), Meerabai *et al.* (1992) and Kabeerthumma *et al.* (1999). The increase in yield and yield attributes with the application of green manure under irrigated conditions may be attributed to the faster decomposition and greater availability of the nutrients for enhanced growth and dry matter production leading to significantly higher yield and yield attributes under irrigated conditions. The beneficial effects of green manure on the yield and yield attributes noticed in the present investigation may also be attributed to the increase in organic matter content and available plant nutrients in addition to improvement in the microbiological and physical properties of the soil, besides

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enhancement of the soil fertility status upon green manuring (Gaur *et al.*, 1984; Joseph, 1986; Krishnamoorthy and Mathan, 1995).

A perusal of the different INM treatments involving application of vermicompost, farm yard manure and green manure organics in conjunction with different doses of the inorganic fertilizers and *Azospirillum* had also revealed tuber yield and yield attributes recorded with the application of vermicompost in combination with *Azospirillum* in conjunction with 2/3rd recommended dose of inorganics (T8) treatments to be on par with the INM treatment resulting in maximum yield and yield attributes (T7—application of recommended inorganics in conjunction with vermicompost and *Azospirillum*) under both rainfed and irrigated conditions during both the years of investigation, indicating a scope for reduction in the dose of inorganic fertilizers needed for cassava production under both rainfed and irrigated conditions by about 33.33 per cent.

5.4 NUTRIENT UPTAKE

The application of organic manures in conjunction with biofertilizer and inorganic fertilizers at different levels was observed to exert a significant influence on the total N, P and K nutrient uptake in addition to the uptake of the nutrients by the stem, leaf and tuber under both rainfed (Tables 14-16) and irrigated (Tables 31-33) conditions during both the years of investigation. Further, the uptake of P was observed to be relatively lower, compared to N and K under both rainfed and irrigated conditions during both the years of investigation. Howeler (1981) reported that cassava being a tuber crop, its P requirement and consequently the P uptake are relatively low, compared to those of N and K, similar to the findings of the present

investigation. The uptake of P and K by stem and tuber was also noticed to be higher in the present investigation, compared to leaf, irrespective of the treatments studied. Similar results were reported earlier in onion (Jayatilake, 2002). Further, the application of inorganics in conjunction with organic manures and biofertilizers (T2 to T13) had in general resulted in higher total N uptake under both rainfed and irrigated conditions during both the years of investigation due to the favourable effect of N in promoting the growth parameters such as plant height, leaf area and number of leaves which in turn might be due to the fact that NAR of N fed plants was accelerated by their increased chlorophyll content and the absorbed N helped in the formation of food reserves due to higher photosynthetic activity which improved carbohydrate content (Kumar *et al.* 1998). Similar findings of higher N uptake with higher N doses applied through organic manure and chemical fertilizers were also reported earlier (Subbaiah *et al.*, 1982; Amirthalingam, 1988; Minahas and Amilsood, 1993; and Mallangouda *et al.*, 1995).

Uptake of P and K nutrients also recorded a similar trend to that of N uptake in the present investigation. Further, Ammanullahkhan (1997) attributed the increased uptake of nutrients under integrated application of organic and inorganic fertilizers to the increased supply and availability of nutrients by the applied organic and inorganic fertilizers. The beneficial effect of organic manures in increasing the available N content was also reported by Grewal *et al.* (1981), while the increased availability of K due to application of FYM was reported by Sandhu and Meelu (1974).

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The application of recommended dose of inorganics in conjunction with organic manures and *Azospirillum* (T3, T7 and T11) was also observed to in general result in higher total N uptake, compared to the application of recommended dose of inorganics in conjunction with organic manures (T2, T6 and T10) due to contribution of N by the applied biofertilizer through its fixation in the soil (Subba Rao, 1984). Similar results were reported earlier (Jayatilake, 2002). Further, an increase in P uptake with increase in N uptake was reported by Subbalaah (1994) and Jayatilake (2002). Similar results were also observed in the present investigation. The uptake of K by cassava tubers was also reported to increase with increasing N and K application (Rajendran *et al.*, 1976). The findings of the present investigation are also in conformity with the above reports. Further, the existence of significant positive correlation for K uptake with tuber yield and dry matter production was also reported by Thampatti and Padmaja (1987), similar to the findings of the present investigation.

The application of recommended NPK fertilizer dose along with vermicompost and *Azospirillum* (T7) was in general observed to result in maximum total N, P and K uptake in addition to uptake of the N, P and K nutrients by stem, leaf and tuber under both rainfed and irrigated conditions during both the years of investigation, due to maximum dry matter production recorded for the treatment as result of maximum stature of the different growth attributes studied in the present investigation. The treatment had also recorded maximum tuber yield in the present investigation under both rainfed and irrigated conditions during both the years of investigation. Similar results were reported earlier in onion (Jayatilake, 2002),

wherein a positive and significant association of bulb yield was observed with total N uptake. Further, application of vermicompost in conjunction with recommended dose of inorganic fertilizers (T6) and different levels of inorganics and biofertilizer (T8 and T9) had also in general resulted in significantly higher total N, P and K uptake, in addition to uptake of the nutrients by stem, leaf and tuber, compared to application of inorganics alone (T1) under both rainfed and irrigated conditions during both the years of investigation. Increased uptake of N, P and K with the application of vermicompost and inorganic fertilizers may be due to better availability of the nutrients due to adequate supply of nutrients and increased mycorrhizal activity (Kale *et al.*, 1987) resulting in better adsorption of water and nutrients. Organic manures were also reported to increase the availability of nutrients in the soil leading to increased uptake of N, P and K by the plant (Ravindrababu, 1999) due to an increase in the activity of native soil nutrients as a result of organic matter decomposition and also due to the high N, P and K content in vermicompost (Sugiv *et al.*, 1994). Similar beneficial effects of vermicompost application in cassava on nutrient uptake by the crop were reported earlier by Ammanullahkhan (1997). Several workers had also reported the uptake of different nutrients to be significantly higher with vermicompost, compared to FYM (Srinivasreddy and Umamahesh, 1995), similar to the findings of the present investigation. Ravindrababu (1999) attributed the increased nutrient uptake with vermicompost to increased amount of dry matter in leaf, root and total plant due to release of more nutrients into the soil upon its decomposition. Further, vermicompost application was reported to render plant nutrients and growth

substances into plant assimilable forms resulting in greater uptake of the nutrients (Kale *et al.*, 1987). Lee (1985) also reported that vermicompost application had resulted in an enhancement of the soil properties such as water holding capacity and porosity of the soil resulting in the higher availability of N, P and K nutrients leading to their greater uptake.

The application of FYM in combination with *Azospirillum* and different doses of the inorganic fertilizers (T2-T5) was also observed in general to result in increased total N, P and K nutrient uptake, compared to the application of inorganics alone (T1) under both rainfed and irrigated conditions during both the years of investigation due to an increase in dry matter production, resulting from increased stature of the growth attributes. Similar results were reported earlier by (Ammanullahkhan (1997) and Renuka (1998).

A perusal of the different INM treatments involving application of vermicompost, farm yard manure and green manure organics in conjunction with different doses of the inorganic fertilizers and *Azospirillum* had also revealed nutrient uptake recorded with the application of vermicompost in combination with *Azospirillum* in conjunction with 2/3rd recommended dose of inorganics (T8) treatments to be on par with the INM treatment resulting in maximum nutrient uptake and yield (T7 – application of recommended inorganics in conjunction with vermicompost and *Azospirillum*) under both rainfed and irrigated conditions during both the years of investigation, indicating a scope for reduction in the dose of inorganic fertilizers needed for cassava production under both rainfed and irrigated conditions by about 33.33 per cent.

5.5 CORRELATION STUDIES

Correlation studies are useful to ascertain the real components of yield which is a complex character. The correlation coefficients indicate the degree of relationship between characters but it alone does not give clear picture of association between yield and its attributes.

In the present investigation correlation studies showed that the tuber yield of cassava had in general recorded a significant positive association with all growth and yield attributes and also with N, P and K uptake during both the years of study under both rainfed (Tables 16a-16b) and irrigated (Tables 33a-33b) conditions. Tuber yield of cassava had recorded highly significant positive correlation with plant height, stem girth, leaves per plant, leaf area index and total dry matter during the two years of study under both irrigated and rainfed conditions. This clearly indicates that increased leaf number per plant and leaf area index might have helped in better light interception and thereby increased photosynthetic efficiency and better translocation of carbohydrates from source (leaves) to sink (tubers) resulted in increased yield. The existence of positive significant correlation between yield and growth attributes namely plant height, leaf number per plant, LAI and total dry matter production was earlier reported by Ramanujam and Biradar (1987) and Ammanullahkhan (1997) in cassava and Jayatilake (2002) in onion, similar to the present findings.

The growth analysis parameters CGR and NAR have also recorded significantly positive association with tuber yield of cassava during both years of study under irrigated conditions. Similar positive significant correlations were

reported earlier by Chowdhury and Ravi (1990) which are in conformity with the present findings.

A highly significant positive correlation existed between tuber yield and yield attributes namely tuber number per plant, tuber length and tuber diameter during both the years of study under both rainfed and irrigated conditions. Similar significant positive correlations were reported earlier by Ammanullahkhan (1997) in cassava and Naskar *et al.* (1992) in sweet potato. It is obvious that increased tuber number per plant and tuber size might have contributed for increased tuber yield of cassava as a result of enhanced translocation of carbohydrates from source to sink.

Further, tuber yield of cassava recorded positive significant correlation with N and P uptake and strongly significant positive association with K uptake during both 2002-03 and 2003-04 years of investigation under both rainfed and irrigated conditions. This clearly indicates that the increased ability of cassava crop to uptake sufficient nutrients results in the increased growth attributes especially, leaf number, leaf area and leaf area index thus resulted in enhanced synthesis of photosynthates and its translocation from source to the sink. The present findings were in conformity with earlier reports by Jayatilake (2002), who reported similar positive significant correlations between yield and nutrient uptake.

5.6 ECONOMICS

The different integrated nutrient management treatments studied in the present investigation were observed to profoundly influence the gross and net returns in addition to benefit : cost ratio of cassava (Tables 17 and 34). Higher gross and net returns were found with the application of inorganics in conjunction with

organics and biofertilizer (T2 to T13), compared to application of inorganics alone (T1) under both rainfed and irrigated conditions during both the years of investigation due to the high yield recorded for application of organics in conjunction with inorganics and biofertilizer, compared to the application of inorganics alone. Ammanullahkhan (1997) also reported higher gross and net returns in organic manurial combinations, compared to no organic manure control. Further, application of recommended dose of inorganics in conjunction with vermicompost and *Azospirillum* (T7) was observed to result in maximum gross returns under both rainfed and irrigated conditions during both the years of investigation due to maximum yield recorded by the treatment, in comparison to other INM treatments studied. However, the total expenditure was also noticed to be high for the treatment, owing to the high cost of vermicompost (Rs 2,000/- per ton), in comparison to farm yard manure (Rs 200/- per ton) and green manuring (Rs 1175/- per hectare), under both rainfed and irrigated conditions during both the years of investigation, resulting in relatively reduced net returns for the treatment. The findings are in conformity with the reports of Ravindrababu (1999). He however, opined that application of vermicompost in the long run may result in increased net returns due to a reduction in the quantity of vermicompost required in subsequent years. He further opined that the cost of vermicompost treatment could still be reduced through the preparation of vermicompost by the farmer himself.

In the present investigation, maximum net returns were recorded for application of 2/3rd dose of recommended inorganics in conjunction with farm yard manure and *Azospirillum* (T3) under both rainfed and irrigated conditions during

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both the years of investigation due to the relatively average cost of the organic component and considerable reduction in the cost of inorganics coupled with the relatively high tuber yields recorded for the treatment. In contrast, maximum benefit : cost ratio was recorded for the application of $\frac{1}{2}$ dose of recommended inorganics in conjunction with green manure and *Azospirillum* (T13) owing to the minimum cost of the organic component and large savings in the cost of inorganics in spite of relatively low yields in general, compared to the application of vermicompost and FYM applied either alone with the inorganics or in conjunction with inorganics and the biofertilizer under both rainfed and irrigated conditions during both the years of investigation.

5.7 CONCLUSIONS

In the present studies on integrated nutrient management of cassava under rainfed and irrigated conditions during two consequent years, the beneficial effects of conjoint application of organics, inorganics and biofertilizers (T2 – T13), compared to the application of inorganics alone (T1) was clearly established on growth attributes, dry matter production and partitioning, growth analysis, yield and yield attributes in addition to NPK nutrient uptake. The economic advantage of integrated nutrient management with the integrated application of organics, inorganics and biofertilizer was also established in the present investigation.

Among the organic manures studied, application of vermicompost in conjunction with inorganics and *Azospirillum* (T6 - T9) had in general recorded greater growth attributes, dry matter production and partitioning, in addition to growth analysis and NPK nutrient uptake resulting in enhanced yield attributes and

thereby increased tuber yield of cassava. Further, application of vermicompost in conjunction with recommended dose of inorganic fertilizers and *Azospirillum* (T7) was observed to result in maximum tuber yield, yield attributes and NPK uptake in addition to maximum dry matter production, CGR, NAR and growth attributes under both irrigated and rainfed conditions during both the years of investigation indicating the potential of the INM treatment in enhancing cassava crop yields under both rainfed and irrigated conditions. Application of 2/3rd dose of inorganics in conjunction with vermicompost and *Azospirillum* (T8) was also observed to result in yield and yield attributes on par with the application of vermicompost in conjunction with recommended dose of inorganic fertilizers and *Azospirillum* (T7) under both rainfed and irrigated conditions during both years of investigation indicating a scope for realization of higher cassava yields with reduced dose of inorganics resulting in reduced cost of cultivation and maintenance of soil health. The gross returns were also observed to be higher with the adoption of INM treatments involving vermicompost component (T6 – T9). However, the net returns and benefit : cost ratio were low in the INM treatments with vermicompost component owing to the high cost of vermicompost indicating the need for reducing the cost of vermicompost through encouragement of vermicompost production by the farmer himself, prior to adoption of the above superior INM treatments involving vermicompost component (T7 and T8) for improvement of cassava yields under rainfed and irrigated conditions of the Andhra Pradesh state.

The application of farm yard manure in conjunction with different doses of inorganic NPK fertilizers and *Azospirillum* (T2 – T5) had also recorded significantly

higher yield and yield attributes in addition to growth attributes, dry matter production, CGR and NAR, compared to the application of inorganics alone (T1). The net returns were also in general higher with INM treatments involving farm yard component due to the relatively high yields coupled with the average cost of the organic component involved corroborating the existing recommendation for use of farmyard manure in conjunction with inorganic fertilizers for increased, economic and sustainable production of cassava under both rainfed and irrigated conditions of the state.

The application of green manure in conjunction with different doses of inorganic NPK fertilizers and *Azospirillum* (T10 – T13) had also in general resulted in higher yields, compared to the application of inorganics alone (T1). The benefit: cost ratio was also in general higher with INM treatments involving green manure component in spite of the relatively low yields, compared to INM treatments involving vermicompost and FYM organic components, due to the low cost of green manure, indicating the feasibility for use of *in situ* green manuring with cowpea in conjunction with inorganic fertilizers and *Azospirillum* for economic and sustainable production of cassava under both rainfed and irrigated conditions of the state.

Chapter VI

Summary

CHAPTER VI

SUMMARY

The present investigation on integrated nutrient management of cassava was undertaken at Agricultural Research Station, Peddapuram, East Godavari district of Andhra Pradesh under rainfed and irrigated conditions during *Kharif* 2002-03 and *Kharif* 2003-04. The experiments were carried out with cv. Sree Prakash (S-856) of cassava with 13 different INM treatments including the application of recommended dose of inorganic fertilizers (T1); application of recommended dose of inorganic fertilizers in conjunction with the organics, namely, farm yard manure (T2), vermicompost (T6) and *in situ* green manuring with cowpea (T10); application of recommended dose of inorganics and *Azospirillum* in conjunction with the organic manures, namely, farm yard manure (T3), vermicompost (T7) and *in situ* green manuring with cowpea (T11); application of 2/3rd dose of recommended inorganics in conjunction with *Azospirillum* and the organic manures namely, farm yard manure (T4), vermicompost (T8) and *in situ* green manuring with cowpea (T12); in addition to application of 1/2 dose of recommended inorganics in conjunction with *Azospirillum* and the organic manures namely, farm yard manure (T5), vermicompost (T9) and *in situ* green manuring with cowpea (T13) on well drained sandy loam soils in a randomized block design with three replications and data was recorded on effect of the different treatments with regards to growth characters, dry matter production and partitioning, growth analysis parameters, yield, yield attributes, quality and nutrient uptake. Further, correlations among growth and yield

attributes, nutrient uptake and yield of cassava and economics of the different treatments was also worked out.

Plant height, stem girth, number of nodes per plant, dry matter production, crop growth rate and net assimilation rate were increased progressively with an increase in the crop age up to harvest. However, the rate of increase was in general rapid from 60 to 150 DAP for the growth attributes; 90-120 DAP and 120-150 DAP for dry matter production, and 120-150 DAP for crop growth rate and net assimilation rate. Thereafter, the increase in growth attributes and dry matter production, was marginal, while number of leaves, leaf area per plant, leaf area index, CGR and NAR were declined at the later stages of crop growth (180 and 210 DAP) due to the senescence of older leaves. An analysis of dry matter partitioning at harvest also revealed the translocation of major share of photosynthates to the tuberous roots (ranging about 54-55 per cent), and retention of moderate amounts in the stem (25-28%) and in the leaves (18-20 %). Further, a perusal of results on N, P and K uptake revealed lower uptake of P, compared to N and K. Further, the uptake of P and K by stem and tuber was noticed to be higher, compared to leaf.

The application of organic manures in conjunction with bio-fertilizer and inorganic fertilizers at different levels (T2 – T13) was in general exerted a significant influence on growth attributes, CGR, NAR, dry matter partitioning at harvest, dry matter production at the different growth stages, shoot/root ratio, tuber yield, yield attributes and nutrient uptake under rainfed and irrigated conditions, during the different years of investigation. The different integrated nutrient management treatments studied in the present investigation were also observed to

profoundly influence the gross and net returns in addition to benefit : cost ratio of cassava. However, the tuber quality attributes did not record any significant influence due to the different INM treatments studied.

The application of recommended NPK fertilizer dose along with vermicompost and *Azospirillum* (T₇) had in general resulted in maximum growth attributes, dry matter production, CGR, NAR, yield, yield attributes and nutrient uptake in addition to minimum shoot/root ratio during both the years of investigation under both rainfed and irrigated conditions indicating the potential of the INM treatment in enhancing cassava crop yields under both rainfed and irrigated conditions. The treatment was also observed to result in maximum gross returns. However, total expenditure was high for the treatment, owing to the high cost of vermicompost resulting in relatively reduced net returns. Further, the application of 2/3rd recommended dose of inorganic fertilizers along with vermicompost and *Azospirillum* (T₈) was also in general resulted in growth attributes, dry matter production, tuber yield, yield attributes and nutrient uptake on par with recommended dose of inorganic fertilizer applied in conjunction with vermicompost and *Azospirillum* (T₇) during both years of investigation and under both rainfed and irrigated situations, indicating a scope for realization of higher cassava yields with reduced dose of inorganics resulting in reduced cost of cultivation besides maintaining of soil health. The application of vermicompost and *Azospirillum* in conjunction with recommended dose of inorganics (T₆) and ½ dose of inorganics (T₉) had also resulted in significantly higher growth attributes, yield, yield attributes and dry matter production at most of the growth stages in addition to higher nutrient

uptake, during the two years of investigation under both rainfed and irrigated conditions, compared to application of recommended dose of inorganic fertilizers only (T1). The gross returns were also observed to be higher with the adoption of INM treatments involving vermicompost component (T6 – T9). However, the net returns and benefit : cost ratio were low in the INM treatments with vermicompost component owing to the high cost of vermicompost indicating the need for reducing the cost of vermicompost through encouragement of vermicompost production by the farmer himself.

Application of FYM in combination with recommended inorganic fertilizers (T2), and with *Azospirillum* in conjunction with recommended (T3) / reduced levels of inorganic fertilizers (T4 and T5) had however, resulted in growth attributes on par with the application of recommended fertilizer dose (T1) in the initial stages (60 DAP) under rainfed conditions, while significantly higher growth attributes were observed for the treatments at later growth stages (120, 150, 180, and 210 DAP). In contrast, significantly higher growth attributes were recorded for application of FYM in conjunction with different levels of recommended dose of inorganic fertilizers and bio-fertilizers under irrigated conditions (T2, T3, T4 and T5) even in the initial stages (60 DAP) compared to application of recommended dose of inorganic fertilizers (T1).

The application of FYM in combination with recommended inorganic fertilizers (T2) and with *Azospirillum* in conjunction with recommended (T3) and reduced levels of inorganic fertilizers (T4 and T5) had also resulted in total dry matter production significantly higher to application of recommended inorganic

fertilizers only (T1). Further, application of $2/3^{\text{rd}}$ and $1/2$ dose of recommended inorganic fertilizers in conjunction with FYM and *Azospirillum* (T4 and T5) had also resulted in dry matter production on par with the application of full recommended dose of inorganic fertilizers in conjunction with FYM (T2) and *Azospirillum* (T3) under both rainfed and irrigated conditions, during both the years of investigation, indicating a scope for saving of inorganic fertilizers.

The application of FYM and *Azospirillum* in conjunction with recommended dose of inorganics (T3) and application of FYM and *Azospirillum* in conjunction with $2/3^{\text{rd}}$ level of inorganic fertilizers (T4) had also recorded tuber weight per plant and yield per hectare significantly higher to application of recommended inorganic fertilizers only (T1) under both rainfed and irrigated conditions during both years of investigation. However, the application of FYM in conjunction with recommended dose of inorganics (T2) had also resulted in tuber weight per plant and yield per hectare significantly higher to that, compared with the application of inorganics only (T1) under irrigated conditions. Further, application of FYM in combination with *Azospirillum* in conjunction with $1/2$ level of inorganic fertilizers (T5) had also resulted in tuber weight per plant and yield per hectare significantly higher compared with the application of inorganics only (T1) and on par with the application of recommended inorganics and FYM (T2) under irrigated conditions, indicating a scope for saving of inorganic fertilizers under irrigated conditions. The above treatments (T2 and T4) had however, recorded tuber weight and yield per hectare on par with the application of inorganics alone (T1) under rainfed

under rainfed conditions. The application of FYM in combination with *Azospirillum* and different doses of the inorganic fertilizers (T2 - T5) was also observed to in general result in increased total N, P and K nutrient uptake, compared to the application of inorganics alone (T1) under both rainfed and irrigated conditions during both the years of investigation due to an increase in dry matter production, resulting from increased stature of the growth attributes. The net returns were also in general higher with INM treatments involving farm yard component due to the relatively high yields coupled with the average cost of the organic component involved corroborating the existing recommendation for use of farm yard manure in conjunction with inorganic fertilizers for increased, economic and sustainable production of cassava under both rainfed and irrigated conditions of the state. Maximum net returns were also recorded in the present investigation for application of 2/3rd dose of recommended inorganics in conjunction with farmyard manure and *Azospirillum* (T3) under both rainfed and irrigated conditions during both the years of investigation.

Application of green manure in combination with recommended inorganic fertilizers (T10), and with *Azospirillum* in conjunction with recommended (T11) / reduced levels of inorganic fertilizers (T12 and T13) had resulted in growth attributes on par with the application of recommended fertilizer dose (T1) in the initial stages (60 DAP) under rainfed conditions, while significantly higher growth attributes were observed for the treatments at later growth stages (120, 150, 180, and 210 DAP). The growth attributes recorded for green manurial treatments in conjunction with different levels of recommended dose of inorganic fertilizers and

bio-fertilizer were however, non-significant compared to application of recommended dose of inorganic fertilizers at 60 DAP under both rainfed and irrigated conditions, probably due to *in situ* incorporation of green manure at 45 days after planting of cassava under both rainfed and irrigated conditions. In contrast, the application of green manure in combination with recommended inorganic fertilizers (T10); and with *Azospirillum* in conjunction with full recommended (T11) and reduced levels of inorganic fertilizers (T12 and T13) had recorded dry matter production significantly higher to application of inorganic fertilizers alone (T1) at later stages of crop growth namely, 150 and 180 DAP under both rainfed and irrigated conditions during both the years of investigation. The dry matter production at early crop growth stages namely, 30, 60, 90 and 120 DAP was however, observed to be on par with the dry matter production recorded for application of inorganics alone (T1). The above treatments had also in general recorded lower shoot/root ratio, compared to the application of inorganics alone (T1), under both rainfed and irrigated conditions during both the years of investigation. Application of green manure in conjunction with *Azospirillum* and different levels of inorganic fertilizers (T10 to T13) had also in general recorded yield and yield attributes on par with the application of recommended inorganic fertilizers only (T1) under rainfed conditions during both the years of investigation, probably due to unavailability of sufficient nutrients in these treatments under rainfed conditions, resulting from the slow and delayed decomposition of organic material applied under restricted moisture conditions. In contrast, the treatments (T10 to T12) had recorded significantly higher yield and yield attributes, compared

to the application of recommended inorganic fertilizers only (T1) under irrigated conditions during both the years of investigation. The benefit : cost ratio was also in general higher with INM treatments involving green manure component in spite of the relatively low yields, compared to INM treatments involving vermicompost and FYM due to the low cost of green manure, the organic component involved indicating the feasibility for use of *in situ* green manuring with cowpea in conjunction with inorganic fertilizers and *Azospirillum* for economic and sustainable production of cassava under both rainfed and irrigated conditions of the state. Maximum benefit : cost ratio was also recorded for the application of ½ dose of recommended inorganics in conjunction with green manure and *Azospirillum* (T13) under both rainfed and irrigated conditions during both the years of investigation indicating its potential for enhanced returns to cassava farmers.

The correlation studies have shown a significant positive association between yield and various characters studied viz., plant height, stem girth, leaves per plant, LAI, total dry matter, CGR, NAR, tubers per plant, tuber length and diameter and N, P and K uptake during both the years under both rainfed and irrigated conditions indicating that the tuber yield of cassava largely depends on these characters.

Future line of work

- Cassava being well adapted to a wide range of soil and climatic conditions, it can be introduced into various cropping systems and nutrient management practices under such systems need to be studied.
- To reduce the cost of cultivation, recycling of different crop and animal wastes and their possible inclusion in the INM package has to be tested.
- Residual and cumulative effects of different INM practices have to be studied on succeeding crops.

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Note: The pattern of 'Literature cited' presented above is in accordance with the "Guide lines" for thesis presentation for Acharya N.G. Agricultural University, Hyderabad.

* Original not seen

Appendix

Appendix I

Weather during 2002-03 cropping period

Month/year	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days
	Maximum	Minimum	at 7.16 hr	at 14.00 hr		
June 2002	35.4	26.6	86	65	60.6	3
July 2002	35.6	26.7	70	50	8.8	1
August 2002	31.5	24.7	89	74	175.3	12
September 2002	30.6	24.7	88	61	85.8	7
October 2002	32.1	22.0	89	66	198.3	9
November 2002	31.4	18.0	87	45	7.2	1
December 2002	31.2	15.5	91	59	-	-
January 2003	29.6	15.3	93	57	11.2	2
Total					536.0	35

Weather during 2003-04 cropping period

Month/year	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days
	Maximum	Minimum	at 7.16 hr	at 14.00 hr		
June 2003	38.2	26.7	83	50	77.5	4
July 2003	31.2	24.5	93	79	314.6	17
August 2003	32.0	25.0	89	75	66.7	9
September 2003	33.5	24.6	88	67	287.6	8
October 2003	31.8	24.5	91	71	208.5	10
November 2003	32.1	20.3	90	50	-	-
December 2003	30.2	16.6	88	49	69.2	2
January 2004	29.1	16.2	94	55	-	-
Total					1024.10	50