

ACKNOWLEDGEMENTS

*I earnestly rever the **Lord VENKATESWARA** for his boundless blessings, which accompanied me in all endeavours.*

*Diction is not enough to express my deep and profound sense of gratitude and indebtedness, reverence and heartfelt thanks to my major Advisor and Chairman of Advisory Committee **Dr. SYED ISMAIL**, Associate Professor of Horticulture and Deputy Director (Ag.), AHRD Project, ANGRAU, Administrative Office, Rajendranagar, Hyderabad, who taught me the way to look into the things regarding subject matter and manner we understand, interpret and present them. His magnanimous attitude, meticulous guidance, constructive criticism, transcendent suggestions, kind treatment and constant encouragement have instilled in me the spirit of confidence and deep sense of respect and gratitude.*

*I owe my respectful regard to **Dr. Y. NARAYANA REDDY**, Professor and University Head, Department of Horticulture, College of Agriculture, Rajendranagar and Member of my Advisory Committee, for his marvelous guidance, constructive acclamation and valuable suggestions during my course work and thesis research.*

*I am extremely grateful to **Dr. T. Y. MADHULETY**, Professor, Department of Plant Physiology, College of Agriculture and Member of my Advisory Committee for his inspiring suggestions and whole hearted co-operation in laboratory analytical work and in presentation of the thesis.*

*I deem it my privilege to extol my profound gratitude and sincere thanks to **Dr. M.V.R. SUBRAHMANYAM**, Professor and Head, Department of Forestry, College of Agriculture, Rajendranagar for his valuable suggestions from time to time and help in the field work.*

*My sincere thanks are due to **Sri M. H. V. BHAVE**, Assistant Professor and **Dr. B. S. KULKARNI**, Professor and University Head, Department of Statistics and Mathematics for their help in statistical analysis of the data.*

*I am immensely thankful to **Dr. S. RIAZUDDIN**, Principal Scientist (Soil Science) ARI, Rajendranagar for rendering help in chemical analysis of soil and plant samples.*

*I accolade my deep sense of honour, love and gratitude to my parents **Sri. N. NARAYAN REDDY** and **Smt. LAXMI** for bringing me up in the best of ways, for rendering me the best of education, for nurturing in me the best of ideals and for helping me to see the best of times.*

*I feel it a rare opportunity to express my bountiful regards, affection and gratitude to my beloved brother **Thirupathi Reddy**, sisters **Shobha** and **Sujatha** and Cousin **Srujana** for their love and affection.*

*With boundless affection and love, I would heartily offer my warm thanks to my best friend **Dr. T. RAVINDHAR REDDY** for his affection, encouragement and moral support showed on me and whose contribution behind the scene has enabled the successful completion of my UG and PG studies.*

*I take this opportunity to say special thanks to my blossom friends and seniors **Sham, Rejeswar Reddy, Lohith, Srikanth, Narsimlu, Raj, Suchi, Venu, Sukumar** and **Israil** for their cooperation and whole hearted helping during the course of investigation and also thanks are due to my classmates **Kishan Rao, Vijayabhaskar, Radha Krishna, Shailaja, Sunanda, Prasanna** and **Bindiya** whose encouragement, affection helped me a lot during my course of study.*

I am indeed greatly thankful to all the teachers of Horticulture department for their suggestions and cooperation rendered during the course of my study and investigation.

*I am greatly thankful to the **Govt. of Andhra Pradesh** for providing financial assistance during the course of my investigation and to **Acharya N.G. Ranga Agricultural University** for giving me this opportunity to pursue my post graduation study.*

*I express thanks to **Krishna Shashank & Aparna Computers** for timely executing the thesis typing work effectively.*

(NAREDDI SUNANDA RANI)

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(NAREDDI SUNANDA RANI)

Author : N. SUNANDA RANI
Title of the thesis : **“PERFORMANCE OF CARROT (*Daucus carota* L.)
UNDER DIFFERENT INTEGRATED NUTRIENT
MANAGEMENT PRACTICES IN BER BASED
CROPPING SYSTEM”**
Degree to which it is submitted : **MASTER OF SCIENCE IN HORTICULTURE**
Faculty : **AGRICULTURE**
Major field : **HORTICULTURE**
Major Advisor : **Dr. SYED ISMAIL**
University : **ACHARYA N.G. RANGA AGRICULTURAL
UNIVERSITY**
Year of submission : **2004**

ABSTRACT

A study was undertaken on the performance of carrot (var. Early Nantes) under different INM practices in ber-based cropping system in a split-plot design replicated thrice during *rabi* season, 2003-04 at Student's Farm, College of Agriculture, Rajendranagar, Hyderabad.

The effect of different organic manures viz., vermicompost, neem cake, castor cake and farmyard manure in conjunction with inorganic fertilizers besides seed treatment with biofertilizers (azatobacter and phosphobacterium) was studied on growth, yield and quality of carrot under different cropping situations in ber plantations i.e., underplanting, intercropping and sole cropping, observing the changes in microclimatic and physiological parameters. Effect of INM practices of carrot crop on associated ber trees was also studied besides economic evaluation of the cropping systems.

In general, cropping systems had a significant effect on the performance of associated carrot crop. Sole carrot recorded maximum root length, girth, dry and fresh weight except plant height which was higher in underplanted crop. Similarly the root yield and quality of carrot crop was superior in sole crop compared to intercropped and underplanted carrot.

Among the different INM practices neem cake in combination with half the recommended dose of NPK recorded maximum plant height, root length, quality (carotene, sugars and TSS content) than other manures. But root girth, fresh and dry weight of carrot was significantly higher with castor cake in combination with half the recommended dose of NPK.

The micro climatic and physiological parameters of carrot crop were also significantly affected by cropping systems, but the INM practices of carrot had no effect. Maximum PAR availability, higher leaf temperature lower relative humidity coupled with lower diffusive resistance and higher transpiration rate was recorded in sole carrot, while the trend was reverse i.e., minimum in underplanted carrot and intermediary in intercropped carrot.

The fruit yield of associated ber trees was significantly influenced by the INM practices of carrot. Neem cake in combination with half the recommended dose of NPK applied to carrot resulted in maximum fruit yield of ber in underplanted situation.

The gross monetary returns were in general higher when carrot was intercropped with ber followed by underplanting compared to sole carrot or sole ber, irrespective of the INM practices adopted. But benefit-cost ratios were higher for sole carrot. The Income Equivalent Ratios (IER) in ber-based cropping system was greater than unity indicating advantage of either underplanting or intercropping of carrot with ber over its sole cropping. Maximum IER of 1.82 in underplanted carrot with neem cake in combination with half of the recommended dose of NPK.

It is concluded that conjunctive use of organic manures (particularly neem cake) with half the recommended dose of NPK and treating the seeds with biofertilizers is highly productive when carrot is planted in ber as intercrop besides its underplanting for effective utilization of available land in the orchard and thereby maximizing economic returns on sustainable basis.

LIST OF SYMBOLS AND ABBREVIATIONS

%	: Per cent
$\mu \text{ mol S}^{-1} \text{ m}^{-2}$	: Micro moles per second per square centimeter
$^{\circ}\text{C}$	: Degree centigrade
$\mu\text{g Cm}^{-2} \text{ S}^{-1}$	: Micrograms per square centimeter per second
B : C	: Benefit : Cost Ratio
C.D.	: Critical difference at 0.05 level of probability
CC	: Castor Cake
cm	: centimeter
cv.	: cultivar
DAS	: Days After Sowing
DSm^{-1}	: Deci simen per meter
<i>et al.</i> ,	: and others
Fig.	: Figure
FYM	: Farm Yard Manure
g plant^{-1}	: gram per plant
i.e.,	: Which is to say, in other words
IC	: Intercropping
IER	: Income Equivalent Ratio
Kg ha^{-1}	: Kilogram per hectare
Kg tree^{-1}	: Kilogram per tree
LER	: Land Equivalent Ratio
m^2	: Square meter
$\text{mg } 100 \text{ g}^{-1}$	: milli gram per 100 grams
mg g^{-1}	: milligram per gram
NC	: Neem Cake
NS	: Not significant
PAR	: Photo synthetically Active Radiation
RD	: Recommended dose
Rs. ha^{-1}	: Rupees per hectare
S. cm^{-1}	: Seconds per centimeter
S.Em.	: Standard Error Means
SC	: Sole Cropping
t ha^{-1}	: tonnes per hectare
UP	: Underplanting
VC	: Vermicompost

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CHAPTER – I

INTRODUCTION

Carrot (*Daucus carota* L.) is an important salad and cooked vegetable, consumed throughout the world. It is a rich source of vitamin A, thiamine, riboflavin, niacin, ascorbic acid and minerals like Fe, Ca and P. The area under carrot in India is 22,358 ha, with annual production of 4.41 tonnes (Natarajan and Veeraraghavathatham, 2001). In tropical and subtropical climate it is grown in winter season. Keeping in view its market demand the farmers are interested to bring more area under carrot cultivation which could be possible through intercropping in orchards.

Being a root vegetable, carrot tolerates shade and performs well in partial shading (Anderson *et al.*, 1988). But the information on the degree of shade this crop tolerates is not available. However studies conducted by Pushpa Kumari and Sasidhar (1992) revealed a severe reduction in yield at intense shade (75%) for different root crops and they recommended cultivation of yam upto 50 per cent shade with 30 per cent reduction in yield, while lesser and elephant foot yam can be grown under only upto 25 per cent shade without much yield reduction. In grown up orchards lot of space under the trees is left unutilized for crop production and only interspaces are generally used for growing shade tolerant crops. There is a need to utilize these areas also for

efficient land utilization and improving per unit area production. In this context the possibility of underplanting of shade tolerant crops can be explored besides their intercropping.

Carrot is a heavy feeder of nutrient and removes 100 kg N, 50 kg P_2O_5 and 180 kg K_2O per hectare (Schaller and Rober, 1985). Therefore judicious and proper use of manures and fertilizers is essential not only for obtaining higher yields and better quality but also to maintain soil health and sustainability. Integrated Nutrient Management (INM) systems envisages the use of organic manures, crop and other organic wastes, bio-fertilizers and inorganic fertilizers. Soil organic matter plays a vital role in keeping the soil productivity high. The conjunctive use of organic manures and fertilizers will not only improve the soil health but also help to maximize sustained production.

Among the concentrated organic manures, oil cakes (neem cake, castor cake etc.) are quick acting though insoluble in water, their nitrogen becomes readily available to the plants in about a week to ten days after application, they provide slow and steady nourishment, stimulation, protection from nematodes and improve yield and quality (composition, taste and flavour) of the produce. According to a conservative estimate made by Singh and Gurumurthi (1984), annual production of non-edible oil cakes was of the order of 3.8 million tonnes. On an average this quantity can furnish 87, 25 and 57 thousand

tonnes of N, P_2O_5 and K_2O respectively. Among the bulky organic manures, vermicompost is a rich source of macro and micro nutrients, vitamins, growth hormones and micro flora produced due to the activity of earthworms (Bhavalkar, 1991). Though Farm Yard Manure (FYM) is not a rich source of nutrients, it increases organic carbon content of the soil and improves soil physical properties.

Bio-fertilizers are living fertilizers, that are efficient in nitrogen fixing, phosphate solubilizing and cellulose decomposing micro organisms. They enhance the availability of nutrients to plants on application to seed or soil and offer an eco-friendly economically viable and socially acceptable means of reducing external inputs of chemical fertilizers (Vikas Singhal *et al.*, 2003). Among the various microbial inoculants Azatobacter and Azospirillum contribute to nitrogen economy of many crops while phosphobacterium help in phosphate solubilization in soil.

The present investigation was aimed at studying the performance of carrot under different cropping situations viz., underplanting, intercropping and sole cropping with the conjunctive use of organic manures (vermicompost, FYM, neem cake and castor cake) and inorganic fertilizers besides the application of bio-fertilizers with the following objectives.

1. To study the effect of conjunctive use of manures viz., vermicompost, neem cake, castor cake and farm yard manure with inorganic fertilizers besides bio-fertilizers on growth, yield and quality of carrot.
2. To study the effect of ber tree canopy on root growth, yield and quality of carrot.
3. To find out a suitable organic manure for carrot under different cropping situations.
4. To workout the economics of cultivation of carrot under different cropping situations with INM practices.

CHAPTER – II

REVIEW OF LITERATURE

The literature pertaining to the effect of Integrated Nutrient Management (INM) practices and cropping systems on the performance of component crops in ber based cropping of carrot besides the economic evaluation of the system is presented hereunder.

2.1 INTEGRATED NUTRIENT MANAGEMENT (INM)

Balanced application of NPK fertilizers offer a better scope for improving the yield and quality of crops. Gattani *et al.* (1976) indicated that continuous use of N and K fertilizers have slightly deteriorated soil physical properties although they could result in higher yields. FYM, on the other hand, helped in maintaining soil structural properties to some extent but failed to give better yield. However, application of N in combination with either P and K or FYM had given encouraging results.

Singh and Yadav (1992) reported that the results of a large number of experiments on manures and fertilizers conducted in the country revealed that neither the chemical fertilizers alone nor organic sources exclusively can achieve the production sustainability of soil as well as crops under high intensive cropping systems. Even the so called balanced use of chemical fertilizers will not be able to sustain high productivity due to the emergence of the deficiency of one or more of secondary and micronutrients (Hedge and Sarkar, 1990).

Singh and Yadav (1992) also reported that Integrated Nutrient Management (INM) helps to restore and sustain soil fertility and crop productivity. It may also help to check the emerging deficiency of nutrients other than N, P and K. Further it brings economy and efficiency in fertilizer use and favourably affects the physical, chemical and ecological environments of the soil.

In a trial with carrot cv. Nantes supplied with cattle manure at 0, 3, or 9 tonnes dunam⁻¹ (dunam = 0.1 ha) or composted municipal waste at 3 tonnes dunam⁻¹ in addition 0, 10, 20 or 30 kg N per dunam, Sugiv *et al.* (1994) found that the highest yield was obtained from the combination of organic manure and N @ 30 kg dunam⁻¹ than alone of them. In this treatment total N, P and K uptake were 22 kg, 5.2 kg and 48 kg dunam⁻¹ respectively.

2.2 ROLE OF ORGANIC MANURES

Kumar and Mathur (1965) reported that application of plentiful organic matter is essential for carrot cultivation and recommended that, 23 tonnes of well rotten manure should be applied to the soil to a depth of 20-25 cm. When organic manure was applied, the need for fertilizer was reduced to 50 kg N, 40 kg P and 50 kg K ha⁻¹ as against 80 kg N, 60 kg P and 60 kg K ha⁻¹ without organic manure.

Iyer and Apte (1967) observed that organic matter application reduced the 'P' fixing capacity of soil but increased its availability.

Application of organic manures, viz., animal manures, urban compost and green manures in conjunction with chemical fertilizers not only improves soil health but also maintains soil fertility and increases crop yields (Glenn, 1976).

The root and leaf mineral contents of carrot also showed an increase when organic manures were applied along with N, P and K fertilizers (Luzzati *et al.*, 1980). Addition of organic manure primarily provides nitrogen to the crops (Larson and Clapp, 1984). The organically bound form of nitrogen becomes available to the crops after undergoing the process of decomposition followed by mineralization into inorganic forms from organic forms. Sharma and Singh (1991) also observed more than two fold increase in available 'P' in the soil after two years in the plots supplied with 60 and 33 kg P ha⁻¹ along with 15 t FYM ha⁻¹ in potato and radish respectively.

The yields obtained with the use of fertilizers and organic manures were higher than the use of inorganic fertilizers alone (Sharma and Dua, 1995). Daniel *et al.* (2002) reported that carrot yields increased significantly with application of organic manures as compared to that of control, the increase being from 16.13 to 16.82 q ha⁻¹.

2.2.1 Vermicompost

Organic manure produced due to the activity of earthworms is commonly referred to as vermicompost. It is a mixture of worm castes,

which is a rich source of macro and micronutrients, vitamins, growth hormones and microflora (Bhavalkar, 1991). Curry and Byrne (1992) found that earthworms derived nitrogen could supply 30 per cent of total crop requirement as it is a potential source of readily available nutrients for plant growth.

Kale *et al.* (1991) reported that quantity of fertilization could be reduced by 25 to 30 per cent in radish, carrot, tomato and brinjal with the application of vermicompost.

Shinde *et al.* (1992) reported that the phosphorus content of vermicompost was more than FYM. Jambhekar (1994) reported that vermicompost contains 2 to 2.5 per cent available nitrogen, 1 to 1.5 per cent available phosphorus, 1 to 1.5 per cent of available potassium and also secondary nutrients like Ca, Mg, micronutrients like Fe, Zn, Mn, Cu and Mo in ample quantities. Further, it contains enzymes like phosphatase, invertase, chitinase etc., and also growth hormones like Indole acetic acid and gibberellic acid.

2.2.1.1 Effect on growth

Neilson (1965) observed improved growth in pastures and in other crops which was attributed to the richness of the earthworm fauna and linked to the chemical exudates of earthworms and microbes in association with them.

Increasing in the levels of vermicompost from 0 to 15 t ha⁻¹ significantly increased the plant height (39.00 cm), leaf number (9.42 plant⁻¹), root length (11.53 cm), root girth (7.68 cm) over control (29.78 cm, 7.49 plant⁻¹, 8.29 cm, 5.76 cm) respectively (Ravindra Babu, 1999).

2.2.1.2 Effect on Yield

Application of earthworm casts in cucumber increased yield by 42.5 per cent over control, while direct release of earthworm in tangerine, grape, orange, apple and nuts increased the fruit yields (Haung and Zhao, 1987).

According to Ravindra Babu (1999), application of vermicompost significantly increased the root yield of carrot over no vermicompost. Among the different levels of vermicompost tried, 15 t ha⁻¹ produced highest root yield (18.96 t ha⁻¹) followed by 10 t ha⁻¹ (14.44 t ha⁻¹) and 5 t ha⁻¹ (12.12 t ha⁻¹).

2.2.1.3 Effect on quality

Tomali *et al.* (1990) observed that incorporation of vermicompost increased protein synthesis by 24 and 32 per cent in lettuce and radish respectively.

In an experiment, cucumber grown in a plastic tunnel and carrot crop grown in the field were fertilized with vermicompost and mineral fertilizers. In both the cases, crop quality was greater with vermicompost than with mineral fertilizers (Kolodzieg and Kostecka, 1994).

Ravindra Babu, (1999) observed that the application of vermicompost at 15 t ha^{-1} increased the TSS (12.62%) and carotene content (5.24 mg/100g) over no vermicompost (12.01% and 4.08 mg/100 g respectively).

2.2.2 Neem cake

Oil cakes universally increased the total inorganic nitrogen content and organic carbon content of the soil as compared to control, indicating the enhanced mineralization of organic nitrogen (Gaur *et al.*, 1992). Oil cakes, in general, increased the available phosphorus content of the soil, due to mineralization of organic phosphorus compounds in soil. Production of organic acids during the course of degradation of different types might play a leading role in this regard (Pareek and Gaur, 1973).

Neem cake increased the efficiency of nitrogen and significant increase in yield due to neem cake blending may well be attributed to the nitrification inhibitory property of neem cake indicating better utilization of applied nitrogen (Prasad, 1979).

Umareddy (1999) reported that application of 100 per cent recommended dose of N through neem cake significantly increased the available P in soil ($38.6 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) over control ($13.44 \text{ kg P}_2\text{O}_5 \text{ kg ha}^{-1}$) and available K in soil ($321.52 \text{ kg K}_2\text{O ha}^{-1}$) over control ($226.19 \text{ kg K}_2\text{O ha}^{-1}$).

2.2.2.1 Effect on growth

Amarendra Kumar *et al.* (1997) reported that application of neem cake significantly increased plant height, girth, number of leaves and number of branches per plant in tomato.

Rao *et al.* (2001) recorded highest leaf number, leaf area, and dry matter production in brinjal when applied with combination of organic manures like neem cake, castor cake etc.

2.2.2.2 Effect on yield

Sharma *et al.* (1986) found that only 105 kg N ha⁻¹ was required when urea was blended with neem cake as against 205 kg N ha⁻¹ through urea for producing 100 q ha⁻¹ yield in radish. Renuka and Snakar (2001) reported that application of neem cake alone or in combination resulted early flowering and highest yields of 2½ times over control in tomato.

2.2.2.3 Effect on quality

Paturde *et al.* (2002) reported that in safed musli, the number of tubers, fresh and dry tuber yield and steroid content increased with application of organic manures like neem cake over control.

2.2.3 Castor cake

Castor cake is a rich source of NPK and micronutrients. It contains ricin, a highly toxic protein, ricinine a relatively harmless alkaloid and an extremely potent allergen often referred as castor bean allergen. Castor cake is generally available for manurial use in large quantities at

relatively lower prices than other seed meals. It ranks high as a source of organic nitrogen.

Malathi (1986) reported that with increasing levels of castor cake from 10 to 40 t ha⁻¹ significantly increased the available N, P and K in soil.

2.2.3.1 Effect on growth

Application of castor cake significantly increased the plant height, root length and root girth of carrot over control (Praveen Kumar, 2000).

2.2.3.2 Effect on yield

Saxena and Singh (1980) found that application of castor cake at 25 q ha⁻¹ significantly increased potato tuber yield and N, P and K in comparison with 250 q ha⁻¹ Farm Yard Manure. Sandhya Rani (1998) reported that application of castor cake at 6 t ha⁻¹ along with nitrogen @ 50 kg ha⁻¹ gave higher yield and uptake of nutrients in radish. Application of castor cake significantly increased the fresh weight of root in terms of root yield (175.71 ha⁻¹) at 6 t ha⁻¹ in carrot (Praveen Kumar, 2000).

2.2.2.3 Effect on quality

Application of castor cake and nitrogen significantly increased the Total Soluble Solids (TSS) content (13.11%) at 6 t ha⁻¹ of castor cake over control (12.54%) in carrot (Praveen Kumar, 2000).

2.2.4 Farm Yard Manure

Farm Yard Manure occupies an important position among bulky organic manures. Farm Yard Manure application increase the organic carbon content of the soil (Sharma *et al.*, 1980). Singh *et al.* (1980) reported that application of farm Yard Manure resulted in significant increase in total and available nitrogen content in soil. Farm Yard Manure has been reported to enhance the availability of phosphorus in acid soils (Prasad *et al.*, 1981).

Gaur (1991) reported that Farm Yard Manure on an average contains 0.5 to 1.0 per cent nitrogen, 0.15 to 0.2 per cent P_2O_5 and 0.5 to 0.6 per cent K_2O and has been estimated that a tonne of Farm Yard Manure would supply 3.6 kg N, 1.9 kg P_2O_5 and 1.8 kg K_2O . Cattle excreta based Farm Yard Manure in India can potentially supply approximately 3.3 million tonnes of N, P and K per year (Gaur *et al.*, 1992).

2.2.4.1 Effect on growth

Anjaiah (2002) found that plant height, root length and root girth of carrot significantly increased with increasing levels of potassium and Farm Yard Manure (FYM).

2.2.4.2 Effect on yield

Sud *et al.* (1990) showed that Farm Yard Manure @ 20 t ha⁻¹ increased the potato tuber yield by 77q ha⁻¹ and it decreased the nitrogen dose marginally from 181 to 163 kg ha⁻¹.

In certain Alfisols, Minhas *et al.* (1994) observed that application of animal manure at the rate of 10 t ha⁻¹ increased the potato tuber yield significantly over control (5.65 to 7.31 t ha⁻¹). Bohm and Dewes (1997) reported an increase in tuber yield with increasing levels of Farm Yard Manure. Anjaiah (2002) found that the carrot root yield increased significantly with increased levels of Farm Yard Manure.

2.2.4.3 Effect on quality

Indumathi (2000) reported an increase in total soluble solid content in radish roots with application of FYM and recommended dose of fertilizers. Application of potassium in combination with FYM recorded significant increase in carotene, TSS and sugar content of carrot with increasing levels of K and FYM (Anjaiah, 2002).

2.2.5 Bio Fertilizers

Bio-fertilizer is a living fertilizer composed of microorganisms which are able to fix atmospheric nitrogen. Bio fertilizers are efficient nitrogen fixing, phosphate solubilizing or cellulose decomposing microorganisms. They enhance the availability of nutrients to plants on application to seed or soil and offer an eco-friendly economically viable and socially acceptable means of reducing external input of chemical fertilizers (Vikas Singhal *et al.*, 2003).

2.2.5.1 Effect on growth

Meshram and Shinde (1990) reported that inoculation of *Azotobacter* to onion increased the diameter of onion bulb (4.66 cm) over control (4.05 cm). Kshirsagar *et al.* (1994) observed an increase in fresh weight of plants with inoculation of *Azotobacter* and VAM in onion cv. N-53. Inoculation of bio fertilizer increased the tuber size in potato (Kamla Singh, 2000).

The two equal splits of 100 per cent NPK with bio fertilizers, viz., *Azospyrillum* and *phosphobacterium* significantly influenced the dry matter accumulation by different plant parts of potato at different stages of plant growth (Mahendran *et al.*, 1996).

2.2.5.2 Effect on yield

Tilak (1991) reported 30 to 50 per cent increase in tuber yield in potato due to inoculation of *phosphobacteria*. The use of 45 kg N ha⁻¹ in combination with *Azotobacter* increased the carrot productivity by 50 per cent over the recommended dose of 60 kg N ha⁻¹ (Wange, 1996).

Kamla Singh (2000) observed that tuber treatment of potato with *Azotobacter* and *phosphobacterium* increased the yield of large tubers and gave the highest net returns.

2.2.5.3 Effect on quality

Panwar *et al.* (2000) reported in radish; application of *Azotobacter* and *Azospirillum* increase the seed protein content, compared to the uninoculated plants.

2.3 ROLE OF NITROGEN

Nitrogen being a major element has a profound effect on plant growth and development directly as constituent of proteins and also its effect on production of phytohormones in plants. Plants absorb nitrogen in cationic form as ammonium ion (NH_4^+) and in anionic nitrate (NO_3^-) form.

2.3.1 Effect on growth

Roy and Jagadish Seth (1971) found that application of N at 120 kg N ha⁻¹ recorded significantly higher root length than 60 kg N ha⁻¹ in radish cv. Japanese white and also obtained increased diameter of root with the application of N at 120 kg N ha⁻¹ compared with 60 kg N ha⁻¹. Maurya *et al.* (1977) recorded maximum girth of root at 200 kg N ha⁻¹ followed by 50 kg N ha⁻¹. Joshi and Chauhan (1985) obtained highest length of shoot with nitrogen at 200 kg ha⁻¹ but was on par with 150 kg and 100 kg N ha⁻¹ in radish.

Maurya and Goswami (1985) found that application of N at 60 kg ha⁻¹ significantly increased the plant height (38.78 cm) in carrot over 40 kg ha⁻¹ (3.0 cm) as well as number of leaves also superior in case of 60 kg

N ha⁻¹. These results are in line with the findings of Dheshi *et al.* (1965) and Otani (1974).

Singh *et al.* (1995) reported that increasing levels of nitrogen significantly increased the leaf length in radish. Similarly Sridhar (1997) recorded a significant increase in the levels of nitrogen from 0 to 120 kg N ha⁻¹. Among N levels 120 kg N ha⁻¹ recorded highest leaf length, but was on par with 80 kg N ha⁻¹. Bagchi (1982) obtained highest fresh weight of leaves with 180 kg N ha⁻¹ but was on par with 120 kg N ha⁻¹ in beet root.

2.3.2 Effect on Yield

Verma and Bajpai (1964) reported that phosphorus application did not show any significant response on yield of either roots or green foliage, where as nitrogen application at various levels increased the yield of carrot. Nitrogen at 22.5 and 44.5 kg ha⁻¹ gave a yield of 460.5 and 493.8 q ha⁻¹ respectively.

Arora and Mathur (1970) found that application of 80 kg N ha⁻¹ gave significantly more yield (403.3 q ha⁻¹) over 40 kg N ha⁻¹ (365.0 q ha⁻¹), but the differences in yields due to 80 kg and 120 kg N ha⁻¹ (393.7 q ha⁻¹) were very small and not significant in carrot. Roy and Jagdish Seth (1971) observed maximum root length in radish by application of 120 Kg N, 30 kg P or 30 kg K compared to 60 kg N, 60 kg P and 60 kg K ha⁻¹, respectively.

Patil and Gill (1981) reported that in carrot, nitrogen and phosphorus application significantly increased height and fresh weight of tops, fresh and dry matter yields of roots, while potash increased fresh weight of tops and dry matter of roots only. Application of 66 kg N ha⁻¹ was found to be satisfactorily superior to control and 30 kg N ha⁻¹ in increasing all characters.

Skribic (1987) reported that basal application of 60 kg P₂O₅ ha⁻¹ and 90 kg K₂O ha⁻¹ with nitrogen at 120 kg ha⁻¹ gave the highest yield and dry matter content in carrot cv. Fertodivoros. Further nitrogen proved to have no significant effect on dry matter production.

Subhan (1988) stated that application of N, P and K @ 60: 30:125 kg ha⁻¹ gave the maximum yield (25.08 t ha⁻¹) in carrot.

Castellane and Bellingieri (1990) obtained highest yield with 100 kg ha⁻¹ ammonium sulphate and 120 kg ha⁻¹ K fertilization in carrots and beet roots (68.9 t ha⁻¹ for carrot and 12.1 t ha⁻¹ for beet root) compared to control (5.2 and 6.3 t ha⁻¹ respectively) in cultivars Brasilice and Early Wonder respectively.

Sreenivasulu (2000) also reported that increasing dose of nitrogen upto 120 kg N ha⁻¹ increased the root yield compared to lower doses.

2.3.3 Effect on Quality

Freeman and Harris (1951) and Otani (1974) reported that increasing level of nitrogen progressively increased the carotene content

of carrot roots. Matura (1961) observed that maximum accumulation of carotene at 18-20°C when nitrogen was applied 80-90 days after sowing. Nitrogen fertilization at 20°C also increased sugar content.

According to Maurya and Goswami (1985), the combination of P x K and N x P x K were found to be effective in increasing the ascorbic acid content of carrot. The treatment NPK (60: 30: 125 kg/ha respectively) maintained highest value of 7.41 mg/100 g of fresh root pulp while lowest value of 3.06 mg/100 g was estimated under control. With the increasing levels of nitrogen application, corresponding increase in carotene content was observed.

Skirbic (1987) obtained increased sugar content with nitrogen at rates upto 120 kg N ha⁻¹ but at higher rates it fell, whereas highest carotenoid content was produced at 90 and 120 kg N ha⁻¹ respectively in both the cultivars Scarlet Nantes and Formula. On the other hand, Cserni *et al.* (1989) observed no significant effect on dry matter or mono and polysaccharide contents in carrot cv. Fertodivoros, while carotene content increased in proportion to nitrogen application.

Joshi and Patil (1988) obtained highest TSS in root with the application of 90 kg N ha⁻¹ compared with 30 and 60 kg N ha⁻¹ in radish cv. Japanese white. Evers (1989) reported that carrots from plants fertilized with suboptimal doses of N showed tendency to have higher carotene content than those fertilized with optimal nitrogen and the

carotene content increased with increasing growing period. Unfertilized treatments gave higher glucose and fructose and the mean total sugar content of 7.8 per cent and 6.7 per cent in 1985 and 1986 respectively in carrot cv. Nantes duke. Sandhya Rani (1998) reported that in increasing the levels of nitrogen significantly increased the TSS in roots of radish and maximum TSS was observed at 150 kg N ha⁻¹.

Shanmuga Sundaram and Savithri (2002) found the effect of nitrogen fertilizer, singly (60, 120 and 180 kg ha⁻¹) on the yield and quality of carrot cv. Zino. Nitrogen at 240 kg ha⁻¹ resulted in the highest root yield (57.7 t/ha) and root ascorbic acid (6.4 mg/10 g) and nitrate nitrogen (283%) contents. The highest carotene contents were obtained with 240 (16.7 mg/100 g) and 180 (13.6 mg/100 g) kg N ha⁻¹.

2.4 ROLE OF PHOSPHORUS

The beneficial effects of 'P' fertilizer resulted in better root growth, more plant residues and the improvements in the physico-chemical characteristics of the soil (Schmidt, 1954).

The major role played by 'Phosphorus' is in improving the organic carbon status of the soil as opposed to N fertilizer was significant (Maurya and Ghosh, 1972).

2.4.1 Effect on growth

Influences of phosphorus and potash were significant but nitrogen did not affect the length of roots significantly (Maurya and Goswami,

1985). Bhat (1996) reported that the application of phosphorus may not show significant effect on plant height, number of leaves, root diameter except on root length in radish.

2.4.2 Effect on Yield

Basso (1968) conducted a 2 year-trial on carrot cv. Nantes in Italy and found that the greatest increase in root production when 160 kg N ha⁻¹ was applied with 240 kg P ha⁻¹. Bajpai *et al.* (1972) reported that application of 60 kg N ha⁻¹ and 60 kg P ha⁻¹ through fertilizer mixture resulted in maximum yield of 193.3 q ha⁻¹.

Pankov (1976) reported that although P deficiency reduced the yield, the dry matter, sugar and carotene contents increased in P-deficient roots. He also reported that the leaf P and K levels for optimum yields were 0.25 to 0.26 per cent and less than 1.7 per cent respectively. Jorgensen (1978) reported that P₂O₅ application at 75 kg ha⁻¹ enhanced the yields of saleable carrot roots over 16 kg ha⁻¹.

2.4.3 Effect on Quality

Phosphorus at 40 kg N ha⁻¹ and potash at 125 kg ha⁻¹ was most effective in increasing the ascorbic acid content of carrot roots (Otani, 1974).

Emura and Hosoya (1979) reported that high P₂O₅ and K₂O from 1 to 4 kg per tunnel increased the carotene content of roots. With high P₂O₅, the reducing and non-reducing sugar contents were increased in both xylem and phloem in carrots sown under plastic tunnels.

2.5 ROLE OF POTASSIUM

Potassium, which is mostly present in inorganic form in soils, accounts to more than 95 per cent of total potassium. Potassium is known for its role in plant nutrition in a variety of crops directly or indirectly for increasing photosynthetic efficiency, keeping quality, disease and pest resistance etc.

2.5.1 Effect on growth

Field experiment conducted by Pankov (1983) indicated that the soils deficient in potassium reduced plant potassium content, which in turn limited growth and productivity.

Application of potassium @ 125 kg K_2O ha⁻¹ (Maurya and Goswami, 1985) and 50 kg K_2O ha⁻¹ (Devi and Padmaja, 1999) increased tuber or root yield, root length, and root diameter in potato, carrot and cassava respectively. Nitrogen and phosphorus did not affect the diameter of roots while potash (120 K_2O ha⁻¹) significantly affected the root diameter (Maurya and Goswami, 1985).

Anjaiah (2002) found that root length and diameter of carrot significantly increased with increasing levels of potassium.

2.5.2 Effect on yield

Basava Raju (1986) reported that application of potash at the rate of 100 kg K_2O ha⁻¹ significantly increased the carrot yield. Rao (1994) also obtained higher yields of carrot with increased level of potassium.

Increasing levels of potassium (0 kg to 120 kg K₂O ha⁻¹) gave significant increase in yield of carrot and the highest yield was obtained at 120 kg K₂O ha⁻¹ (Anjaiah, 2002).

2.5.3 Effect on quality

Emura and Hosoya (1979) found that the carotene content of carrot increased with application of potassium. Similar results were also reported by Michalick (1985) and Sharangi and Paria (1997).

Rao (1994) reported that there is an increase in root length, yield and carotene content of carrot with increased levels of applied potassium. There was significant improvement in storage life of potato when 100 kg K₂O ha⁻¹ was applied (Dubey *et al.*, 1997).

Soloman *et al.* (1998) observed that the application of potassium reduced the post harvest moisture loss in carrots by maintaining tissue integrity and in turn improved shelf life.

Anjaiah (2002) reported that increasing levels of potassium increased the carotene content, total sugars and total soluble solid content in carrot.

2.6 INTERCROPPING IN ORCHARDS

In the context of orchard or a plantation of perennial fruit trees, the practice of growing annuls or relatively short duration crops in the inter spaces during their formative years is referred to as intercropping. Intercropping is intended to maximize land and space use efficiency to

generate supplemental income particularly during the initial unproductive phase of orchard and to protect the inter spaces from losses through weeds, erosion, impact of radiation, temperature , wind and water and enriching it by nitrogen fixing leguminous crops (Hayes, 1960; Bajwa and Dhillon, 1973; Doss, 1985; Ram and Rajan, 1985). However, if the main plantation is not given priority care, serious losses may occur as a result of root restriction, damage and infection, undue exhaustion of the soil and perpetuation of viral, fungal and nematode infections. Inter crops, therefore should receive only secondary importance (Gandhi, 1939; Naik, 1949; Ramakrishna, 1954; Nijjar, 1980; Ram and Rajan, 1985).

Ewel (1986) opined that there are three potential ecological benefits in having several species in an ecosystem: full use of resources, pest protection and compensatory growth. Increase in species richness and diversity do not always lead to more effective resource use, but in many multi-species plant communities resource use is complementary rather than competitive (Connor, 1983; Willey, 1985). The mechanism of sharing and utilization of above ground and below ground resources in multi-species plant community is complex. However, the pool of resources from which the different components of a system can draw is not unlimited in most agro-ecosystems.

Agro-ecosystems involving trees have several advantages. For example continuity of cover and longevity indicates that the nutrients are circulate without interruption. Evaporation of the soil is reduced. There

are certain limitations too with such system. The yield of annual crop is much higher than those of perennials. Annuals have high net primary productivity, much of which is allocated to the reproductive or storage organs that are harvested as products. The advantage offered by tree-crop admixture is that, it is possible to combine the ecological virtues of perennial polycultures with the high yield that are possible in monoculture of annuals.

Tree-based cropping systems maintain more favourable soil physical properties than agricultural systems through maintenance of organic matter and the root effects. These include soil structure, porosity and water holding capacity (Young, 1989).

2.7 BER AS BASE CROP IN TREE BASED CROPPING SYSTEMS

Among the various dry land fruit trees, Ber (*Ziziphus mauritiana*) being multi purpose in nature and more so because of its adaptability to varied soil and climatic conditions (Pareek, 1983; Chundawat, 1990) is regarded highly suitable for agri-horticultural system. Alleys of ber offer greater possibility of growing crops due to regular annual pruning for fruiting.

Tomar *et al.* (1988) tried three vegetables as intercrops in ber trees spaced 8 m apart in dry lands of semi-arid tropics at Hyderabad. Cluster bean yielded maximum green pods (2263 kg ha⁻¹) without fertilizer

application and its yield increased only by 30 kg with 10:30 N:P fertilizer application.

Korwar *et al.* (1988) at CRIDA, Hyderabad found that agri-horticultural system involving ber and grain legumes or vegetables resulted in higher returns than ber alone. Among the grain legumes tested with cowpea and green gram fared well, but the returns in the latter were higher because of its higher price. Returns from intercropped ber with horse gram were higher when grown for grain purpose than with cluster bean as vegetable.

Through reduction in extremes of soil surface temperature, trees may reduce the rate of loss of soil organic matter by oxidation (Young, 1989).

Raturi and Hiwale (1988) also realized maximum returns from intercropping of ber with cluster bean (short duration) compared to long duration intercrops at Godhra in Gujarat.

The North Eastern Nigeria, *Zizyphus* spp. retain the least amount of leaves during the crop growing wet season. They maintain maximum leaf and fruit production during the dry season. *Zizyphus* trees also favour rapid growth and yield of other plants grown under their canopies and therefore the traditional farmers give equal priority to farming under canopies of both *Faidherbia albida* and *Zizyphus* spp. trees (Verinumbe, 1989).

Gill and Deb Roy (1990) reported maximum grain yield in sorghum (20.87 q ha⁻¹) during *kharif* with sorghum-chickpea rotation in association with ber. This yield was comparable to the yield of sorghum (23.34 q ha⁻¹) in the same rotation under sole cropping.

In four year old ber trees, the yields of sunflower, pigeon pea and castor due to intercropping were not affected and were comparable with the yields of respective sole crops (Syed Ismail *et al.*, 1993).

Verinumbe (1993) observed higher yields of *Leucaena leucocephala* and *sorghum vulgare* under canopies of *Zizyphus spina-christi* rather than the more popular *Faidherbia albida*. The yield superiority of *Zizyphus spina-christi* was explained by larger concentration of phosphorus, potassium and calcium which decrease with the increasing distance from the tree.

In an experiment on ber intercropped with radish and okra at three levels of nitrogen fertilization revealed that intercropping of ber with radish gave higher returns compared to intercropping with okra, because the harvestable product was vegetative and under ground in radish (Reddy, 1997).

2.8 CARROT AS AN INTERCROP IN TREE BASED CROPPING SYSTEMS

In Punjab to protect the loss of soil organic matter from intense summer heat in citrus orchards, carrot was one of the recommended

intercrops suggested by Nijjar (1980) besides other vegetables like turnip, potatoes, peas, radish and cauliflower.

In litchi orchards, Shymal and Verma (1982) have found carrot and other vegetables like cucurbits, cabbage, beet spinach, knol-khol, beet root, onion and cauliflower as suitable intercrops. Maiti (1985) also suggested carrot and other vegetables like radish, turnip, beet etc as intercrops in litchi orchards for *rabi* season.

In west Java (Mauladi *et al.*, 1988) *Linum usitatissimum* was intercropped with carrot, welsh onions, sugar beet, cabbage and radish, carrot and Welsh onion yields were higher from intercropping than the sole crop.

Bajpai and Chaturvedi (1990) suggested that intercropping in Jamun orchard with radish and other vegetable improves soil fertility and brings good income. Dwivedi *et al.* (1991) suggested carrot and other vegetable like potatoes, cabbages and beans as intercrops in fruit tree plantations. Srinivasulu (2002) observed that intercropping of carrot in young guava plantation was highly productive and remunerative compared to grown guava plantation.

2.9 EFFECT OF INTERCROPS ON FRUIT YIELD AND QUALITY OF BER

2.9.1 Fruit yield

Syed Ismail *et al.*, (1993) reported significantly higher fruit yield in sole ber compared to intercropped ber with sunflower, castor or

pigeonpea. Syed Ismail (1994) also recorded significantly higher fruit yield ($21.43 \text{ kg tree}^{-1}$) in sole ber compared to intercropped ber with Palmarosa ($15.47 \text{ kg tree}^{-1}$) and lemon grass ($17.98 \text{ kg tree}^{-1}$) during third year of fruiting. Reddy (1997) observed that the yield of sole ber was significantly higher compared to intercropped with radish and okra.

2.9.2 Average fruit weight

Large sized fruits contribute much towards the yield. Ber cultivars differ greatly in their individual fruit weight. Individual fruit weight in ber cultivar ranged from 5 to 33 g (Chadha *et al.*, 1972). Singh and Tomar (1988) reported that even under semi-arid conditions of Punjab, Umran showed highest fruit weight among the six cultivars of ber. From Rajasthan, Pareek and Vashishtha (1980) reported heavier fruits in Katha (34 g) and very light fruits in Tikadi (3.8 g).

Syed Ismail (1994) reported that the average fruit weight of ber was significantly higher in sole ber compared to intercropped ber. Similar results were also reported by Reddy (1997).

2.9.3 Chemical composition of ber fruits

Syed Ismail (1994) reported that vitamin-C content in sole and intercropped ber with palmarosa or lemon grass did not vary much though the total soluble solids content was higher in sole ber. The titrable acidity was more in intercropped ber with palmarosa and lemon grass. Highest

ascorbic acid content in sole ber compared to intercropped ber was also reported by Reddy (1997).

2.10 EFFECT OF TREE SHADE ON PERFORMANCE OF INTERCROPS

Newman (1986) in an experiment on pear and radish interculture system, reported that the overall transmittivity of the pear canopy was 73 per cent and a 47 per cent reduction in PAR gave a yield reduction of 65 per cent in terms of number of saleable radish, but reduction in radish yield directly beneath pear trees might be due to other factors besides PAR.

Anderson *et al.* (1988) observed that higher concentrations of chlorophyll or lower chlorophyll a:b ratios to benefit performance of intercrop at low light levels under shaded conditions.

Pushpa Kumari and Sasidhar (1992) reported that the tuber yields of four minor tuber crops, viz., greater Yam, lesser yam, tannia and elephant yam were significantly influenced by shade levels. The different crops responded differently to shade intensity. Except tannia, all the other crops recorded their best yields under open (0% shade) conditions, where as severe reduction in yield was observed at intense shade (75%). Tannia yielded maximum at 25 per cent shade which was on par with 50 per cent shade. Thus among the four crops, tannia alone can be recommended as a shade tolerant crop. Greater yam can be recommended for cultivation upto 50 per cent shade with 30 per cent reduction in yield. Lesser and

elephant foot yam can be grown under only upto 25 per cent shade without much yield reduction.

In an intercropping trial with banana intercropped with French bean, there was a reduction in the yield of inter cropped French bean to an extent of 52 per cent over sole crop. Shading reduced yield, but chlorophyll content, and chlorophyll a: b ratio, stem starch levels were not related to seed yield in either system (Wortmann *et al.*, 1992).

Syed Ismail (1994) reported that the tree shade of ber resulted in lower values of growth parameters herbage and oil yield of lemongrass and palmarosa compared to open situation (sole crop).

Emebiri and Nwufo (1994) reported that the vegetable yield of *Telfairia occidentalis* grown at various distances (3.45 and 6 m) from a row of mango trees remained unaffected by proximity to the tree line until about 170 days after planting (the onset of the dry season, when water usually becomes limiting, occurred at 170 DAP). They suggested that crops whose harvestable parts are vegetative tend to be less affected when grown in proximity to trees, but provided water is not limited.

2.11 MICRO-CLIMATIC CHANGES IN TREE-BASED CROPPING SYSTEMS

Syed Ismail (1994) reported that there was a significant reduction in per cent PAR availability on the top of intercrop canopy and also in transpiration. Increased stomatal diffusive resistance of palmarosa and lemon grass in proximity to ber was also noticed.

Bheemaiah *et al.* (1995) also reported similar trend with respect to per cent PAR availability, stomatal diffusive resistance and transpiration besides reporting higher values of relative humidity and lower values of leaf temperature of castor, sunflower and pigeonpea intercropped with *Faidherbia albida*. Similar results were reported by Subrahmanyam *et al.* (1996) with castor under sissoo based intercropping system, Reddy and Syed Ismail (1999) with okra intercropped in ber and Reddy *et al.* (2000) with radish in ber system.

2.12 PRODUCTIVITY EVALUATION OF TREE-BASED SYSTEMS

Evaluation of the basic biological efficiency of given intercropping system is almost always worthwhile in any evaluation process. Biological efficiency is conventionally measured using relative units, but there is much greater scope for using absolute yields. Land equivalent ratio (LER) has been generally accepted as an agronomically sound index for arriving yield advantages derived from inter cropping practice. LER can be defined as the relative area of sole crop that would be required to produce the equivalent yield achieved by intercropping. The concept of LER is the most widely accepted index for evaluating the effectiveness of all forms of intercropping (Willey, 1985). It is the sum of the fractions of the yield of the intercrops relative to their sole crop yields.

Newman (1986) assessed the productivity, land equivalent ratio and light use efficiency of a pear and radish interculture system. Pear yield was

unaffected by intercropping. Relative yields for the radish component varied between 0.5 and 1.01 depending upon the yield index and spatial arrangement employed. This results in LER values of 1.5 to 2.01.

Aiyelaagbe and Jolaoso (1992) at Ibadan, South Western Nigeria reported that the LER value for papaya intercropped with okra was 3.80 indicating that intercropping was more advantageous than mono crop of papaya.

Syed Ismail (1994) while studying tree crop interactions in rainfed perennial intercropping system of ber with aromatic grasses at different nitrogen levels observed that intercropping system resulted in higher gross and net returns compared to sole cropping. IER values were more than unity in the system indicating yield advantage. Maximum IER (1.68) was obtained by intercropping ber with lemon grass at $240 \text{ kg N ha}^{-1} \text{ year}^{-1}$ compared to intercropping with palmarosa. IER which is more relevant in assuming the productivity of the system as a whole was in favour of intercropping ranging from 1.55 to 1.68.

The Income Equivalent Ratio (IER) from ber based intercropping system with radish and okra ranged from 1.59 to 1.72 and 1.43 to 1.48 respectively indicating the superiority of ber based intercropping system over sole cropping as the values of IER were fairly well above unity (Reedy, 1997).

Sreenivasulu (2000) also obtained highest IER values of 1.88 to 1.92 by intercropping of carrot in young guava and 1.29 to 1.33 in grown guava plantation.

CHAPTER – III

MATERIALS AND METHODS

The present investigations were carried out to study the performance of carrot (*Daucus carota* L.) under different Integrated Nutrient Management Practices in ber-based Cropping System during *rabi* season (October 2003 to February 2004), at Students Farm, College of Agriculture, Rajendranagar, Hyderabad situated at 17° 19'N latitude and 78° 23' E at an altitude of 534 m above mean sea level.

3.1 WEATHER

Hyderabad falls under semi arid tropical climate zone with an average rainfall of about 800 mm per annum. Weather data pertaining to rainfall, average weekly minimum and maximum temperatures, relative humidity, evaporation, wind speed and Sunshine hours were recorded during the period of experimentation and are presented in Appendix-A.

The weekly mean maximum temperature during the crop period ranged from 26.8 to 31.1°C with an average of 29.01°C, while mean minimum temperature was between 9.2 to 18.9°C with an average of 13.44°C and the weekly relative humidity at 8.00 hours ranged between 83 to 93 per cent with an average of 87.38 per cent, and the weekly relative humidity at 14.00 hours ranged between 26 to 55 per cent with an average of 39.08 per cent. The weekly mean sunshine hours ranged

between 4.7 to 9.8 hr with an average of 8.16 hrs and the total rainfall of 7.3 mm was received during the crop period with 2 rainy days.

3.2 SOIL CHARACTERISTICS

Soil samples were collected from 0-30 cm depth at random from the experimental area, before laying out the experiment. The collected soil samples were air dried and ground to pass through 2 mm sieve before analysis. The composite soil samples were analyzed for their Physico-chemical properties which are presented in Table 1.

Table 1: Physico-chemical and chemical analysis of the soil

S.No.	Test	Method	Reference	Result
A.	Physical characteristics			
1	Mechanical composition (%)			
i.	Coarse sand	-	-	56.8
ii.	Fine sand	-	-	14.3
ii.	Silt	-	-	16.4
iii.	Clay	-	-	12.5
2	Textural class			Sandy loam
B.	Chemical characteristics			
1	Soil reaction (pH)	1:2.5 Soil : Water suspension	Jackson, 1967	7.0
2	EC (dSm ⁻¹)	Digital EC meter	Jackson, 1967	0.29
3	Organic carbon (%)			0.21
4	Available N (kg ha ⁻¹)	Alkaline permanganate method	Subbiah and Asija, 1956	160.0
5	Available P ₂ O ₅ (kg ha ⁻¹)	Olsen's method	Olsen <i>et al.</i> , 1954	26.0
6	Available K ₂ O (kg ha ⁻¹)	N.N. Ammonium Acetate method	Muhr <i>et al.</i> , 1965	326.0

The soil was red sandy loam of uniform topography and texture. According to soil classification, it is an 'Alfisol' locally known as 'Chalka soil'. The chemical analysis of soil indicated that the soil at the experimental site was neutral in reaction, low in organic carbon and nitrogen, medium in available phosphorus and high in available potassium.

3.3 CROPPING HISTORY OF EXPERIMENTAL SITE

Since 1989, the experimental site was under ber based intercropping system. The ber (var. Gola) was intercropped with palmarosa and lemon grass as perennial intercrops upto January 1993. Thereafter, sunflower, clusterbean and soybean were grown as intercrops till 1995. Radish and okra were raised as intercrops from October 1996 to January 1997. Thereafter the field was under monocropping of ber without growing any intercrops till *rabi* 2003.

3.4 MATERIAL

3.4.1 Tree-crop combinations

The following were the component crops in the cropping system tried.

Tree component : Ber (*Zizyphus mauritiana* Lamk) variety 'Gola' as base crop.

Crop component : Carrot (*Daucus carota* L.) variety ‘Early Nantes’ was raised in association with ber as inter crop or under plant besides raising as sole crop.

Ber belongs to the family Rhamnaceae, which is a popular dryland fruit crop. The tree has spreading habit. Leaves are simple, alternate, ovate to oblong, densely tomentose on under surface. Flowers mostly hemaphrodite, small sized and born in clusters. Fruit is a drupe and elliptical in shape. The variety Gola is fast growing prolific bearer and spreading type. The fruits are roundish, golden yellow in colour, average weight around 25 g and length and diameter of the fruits varies from 3.07 to 3.60 cm and 2.45 to 3.25 cm respectively. It contains TSS 16.00 to 20.00 per cent and acidity varies from 0.14 – 0.25 per cent. It also rich in ascorbic acid content (Vit.C) which varies from 70 mg – 140 mg per 100 g pulp. A mature tree gives an average yield of 85 kg.

Carrot (*Daucus carota* L.) is a well known cool season root crop, widely grown for its fleshy edible roots. It belongs to the family Umbelliferae. The fleshy edible portion of the root develops from the primary root. Being a quick growing and short duration and shade tolerant crop, it is easily grown as an intercrop between the rows of trees or as under planted crop in orchards. Carrot is a rich source of carotene, Total Soluble Solids (TSS) and sugars.

There are two distinct groups of carrot i.e. tropical or Asiatic and temperate or European. The temperate types form roots both under temperate and tropical climates but set seeds only under temperate conditions. The Asiatic types are high yielding, producing seed under tropical conditions. They are poor in carotene content and other quality attributes.

Early Nantes is a temperate or European type. It produces almost cylindrical roots terminating abruptly in small, thin, tail 12-15 cm long, fine textured; orange flesh with self coloured core and it has good consumer performance and marketability.

3.5 FIELD EXPERIMENT

3.5.1 Treatmental details

The main treatments comprised of different cropping systems i.e. intercropping and under planting of carrot with ber trees besides its sole cropping.

The sub treatments comprised of different INM practices consisting of application of inorganic fertilizers alone or inconjunction with organic manure viz., Vermicompost, Neem cake, Castor cake and Farm Yard Manure (FYM).

The details of the treatment combination are given in Table 2 and Fig. 1. The overview of the experiment is shown in Plate 1.

Table 2: Details of the treatment combinations

S.No.	Main treatments	Sub-treatments
I	Under planting of carrot in ber	1. Vermi compost + $\frac{1}{2}$ RD NPK 2. Neem cake + $\frac{1}{2}$ RD NPK 3. Castor cake + $\frac{1}{2}$ RD NPK 4. FYM + $\frac{1}{2}$ RD NPK 5. $\frac{1}{2}$ RD NPK only 6. RD NPK only
II	Inter cropping of carrot in ber	1. Vermi compost + $\frac{1}{2}$ RD NPK 2. Neem cake + $\frac{1}{2}$ RD NPK 3. Castor cake + $\frac{1}{2}$ RD NPK 4. FYM + $\frac{1}{2}$ RD NPK 5. $\frac{1}{2}$ RD NPK only 6. RD NPK only
III	Sole cropping of carrot	1. Vermi compost + $\frac{1}{2}$ RD NPK 2. Neem cake + $\frac{1}{2}$ RD NPK 3. Castor cake + $\frac{1}{2}$ RD NPK 4. FYM + $\frac{1}{2}$ RD NPK 5. $\frac{1}{2}$ RD NPK only 6. RD NPK only

Note: Besides above combinations a separate treatment of sole ber was also included to record observation on ber in sole and intercropping/underplanted situations

3.5.2 Experimental Design

The design of the field experiment was a split-plot with three replications.

3.5.3 Plot size

The gross plot size for each treatment was 4 x 4 m, with in the interspaces of two ber trees for intercropping and a plot of 4 x 4m in the tree basin of ber i.e. 2 m from either side of ber tree for underplanting, besides plot of similar size for sole crop of carrot away from ber trees in the same field (Fig.2)

3.6 MANAGEMENT OF BER TREES IN TREATMENT PLOTS

The existing ber plantation of cv. Gola with 8 x 8 m spacing was utilized for the study. Annual pruning for fruiting was done during third week of April 2003 by removing previous season's growth to sixth secondary and also removal of secondary branches.

Individual trees were fertilized with 1 kg N, 1 kg P_2O_5 and 180 g of K_2O in the form of urea, single super phosphate and muriate of potash respectively with the onset of monsoon.

Necessary plant protection measures against major pests and diseases (fruit fly and powdery mildew) were taken up as and when required.

During fruiting time the tree got the advantage of irrigations given to the intercrop at different intervals. The fruits were harvested during the period from November to January in 4 to 5 pickings as and when matured. Fruits were picked when they were still crisp but developed a light yellowish colour on outer skin.

3.7 DETAILS OF CARROT CULTIVATION

3.7.1 Preparatory cultivation

The experimental field was prepared for sowing by working twice with the tractor drawn cultivator and then blade harrow to bring the soil to fine tilth. The land was perfectly leveled with the bullock drawn wooden planks and the layout plan implemented. Manures and fertilizers were applied as per the treatment in each plot; afterwards ridges and furrows were prepared for carrot 30 cm apart.

3.7.2 Application of manures and fertilizers

Manures like vermicompost (10 t ha^{-1}), neem cake (4 t ha^{-1}), castor cake (4 t ha^{-1}) and FYM (15 t ha^{-1}) were applied in conjunction with 50 per cent recommended dose of NPK in the soil as per the treatment besides 50 per cent recommended dose of NPK and 100 per cent recommended dose of NPK ($100:60:80 \text{ kg N, P}_2\text{O}_5 \text{ and K}_2\text{O}$ respectively) treatments. Half of the nitrogen and full dose of P_2O_5 and K_2O were applied before preparation of ridges and furrows for sowing and the remaining part of nitrogen was applied at 40 DAS. NPK were applied through urea, single super phosphate and muriate of potash respectively.

3.7.3 Seeds and Sowing

Fresh sound seeds of carrot cv. Early Nantes with good germination percentage were selected. The seeds were treated with biofertilizers (Azatobacter and phosphobacterium @ 25 g per kg seeds

each). For this slurry of jaggery was prepared and poured slowly on the seeds mixing evenly to get uniform coating on all seeds, then dried the treated seeds in shade and sown immediately after drying on the ridges already prepared at 30 cm apart. The plant to plant spacing of 5 cm was adopted and two seeds were sown per hill.

3.7.4 Thinning and gap filling

To provide optimum plant population, excess plants were thinned out or gap filled as the case may be after 10 days of germination in each treatment plot.

3.7.5 Irrigation

The first irrigation was given immediately after sowing the seeds in the field and subsequent irrigations were given as and when required, furrow irrigation was adopted.

3.7.6 Weeding and earthing up

Hand weeding were done 20, 40 and 60 days after sowing of carrot. Earthing up was taken at 30 DAS to cover the exposed roots.

3.7.7 Harvesting

The harvesting of carrot was done at 80 DAS, when the roots were fully grown but tender. Prior to harvest light irrigation was given to facilitate their easy pull out along with tops and were washed in running water before marketing.

3.8 DATA COLLECTED ON BER TREES

3.8.1 Fruit yield (kg tree⁻¹)

The fruits were harvested as and when matured. The weight of all the harvested fruits at every picking from individual tree was recorded separately. At the end of the harvesting period, total weight of fruits from all pickings was added to arrive at the final yield per tree (kg tree⁻¹) in each treatment. This was also expressed in t ha⁻¹.

3.8.2 Average fruit weight (g)

Average fruit weight was calculated by weighing 100 randomly selected fruits during picking at the mid fruiting season in each treatment.

3.8.3 Fruit quality

3.8.3.1 Sugar content (Reducing and non reducing sugars)

Total soluble sugars were estimated by Fehling Soxhlet / Lane-Eyno method (AOAC, 1965).

3.8.3.2 Total soluble solids (°Brix)

The Total Soluble Solids (TSS) in fruit pulp were determined by using a hand Erma-Japan refractometer (range 0-26°).

3.8.3.3 Acidity (%)

Percent titrable acidity of ber fruits was estimated by titrating 10 ml of fruit pulp juice against 0.1 N sodium hydroxide using Phenolphthalin indicator (Ranganna, 1986).

3.8.4 Nitrogen content (%)

Nitrogen content in the leaves of ber was estimated by Microkjeldhal method (AOAC, 1969) on dry weight basis.

3.8.5 Phosphorus and Potassium contents (%)

Phosphorus and Potassium contents were determined in the tri-acid extracts after digesting the leaves of ber with tri-acid mixture 9:2:1 (HNO_3 : H_2SO_4 ; HClO_4).

The phosphorus content in the plant digest was determined by Vanado Molybdophosphoric yellow colour method using Klett Summer Sen Photo Electro Calorimeter and potassium content was determined with Elico-Flame Phtometer (Piper, 1966).

3.9 DATA COLLECTED ON CARROT

3.9.1 Plant height (cm)

Plant height was measured from base of the stem at ground level to the tip of the top leaf at 20 days interval upto 80 DAS from five randomly tagged plants under different treatments and means were worked out.

3.9.2 Root length (cm)

Root length from collar region to the tip of the root was measured with scale for five randomly pulled out plants at similar intervals under different treatments.

3.9.3 Root girth (cm)

Root girth was measured at just below the collar region at similar intervals and means were worked out.

3.9.4 Fresh root weight (g plant⁻¹)

The fresh weight of carrot root was recorded immediately after pulling out the roots after through cleaning in each treatment at similar intervals.

3.9.5 Dry weight of root (g plant⁻¹)

The dry weight of root was recorded after oven drying at 80°C till constant weight was obtained in a similar manner.

3.9.6 Shoot and root yield (t ha⁻¹)

The shoot portion was cut close to the collar region at the time of harvest and the shoot and root yield was recorded separately on fresh weight basis per plant and computed on hectare basis.

3.9.7 Shoot to root ratio

The ratio of fresh weight of shoots to roots was calculated from five randomly pulled out plants at harvest (80 DAS).

3.9.8 Microclimatic and physiological parameters recorded on carrot

The following microclimatic and physiological parameters were measured with LI-1600 Steady State Porometer (LI-COR, Lincoln, Nebraska, USA) on diurnal basis in different treatments besides sole crop

at 75 DAS on clear non-cloudy days at 8.00, 12.00 and 16.00 hrs on the top of the carrot crop canopy in the read out control console.

3.9.8.1 Leaf temperature (°C)

Diurnal variation in leaf temperature on the top of the carrot crop canopy was recorded using LI-1600 Steady State Porometer by clamping the leaf in sensor head in contact with thermo couple in each treatment by direct read out of the display on console.

3.9.8.2 Relative humidity (%)

Diurnal variation in relative humidity within the crop canopy was recorded in a similar manner by turning the knobs to Relative Humidity for display.

3.9.8.3 Stomatal diffusive resistance (s cm^{-1})

The diurnal variation in stomatal diffusive resistance of carrot crop under different treatments was measured in a similar manner by rotating the knob to Stomato Diffusive Resistance for display.

3.9.8.4 Transpiration ($\mu\text{g cm}^{-2} \text{s}^{-1}$)

Diurnal variation in leaf transpiration of the crop was recorded similarly by direct read out, turning the knob to the respective position for display.

3.9.8.5 Photosynthetically active radiation ($\mu \text{mol s}^{-1} \text{m}^{-2}$)

The diurnal variation in the Photosynthetically Active Radiation (PAR) available on the top of the carrot canopy in under planted, intercropped, and

sole cropped carrot was measured with LI-1600, Steady State Porometer by direct read out observing the display at quantam position.

3.9.9 Root quality parameters (bio-chemical)

3.9.9.1 Carotene content (mg 100 g⁻¹)

Carotene content of roots was determined from 5 randomly selected roots in each plot at harvest with the procedure suggested by Zakaria *et al.* (1979)

3.9.9.2 Sugar content (Reducing and non-reducing sugars)

Reducing and total sugars were estimated by Fehling Soxhlet Method (Lane-Eyno- Method, AOAC, 1965). From this non reducing sugars were worked out.

3.9.9.3 Total soluble solids (°Brix)

Total Soluble Solids (TSS) in the roots was determined by using a hand Erma-Japan refractometer (range 0-26°).

3.9.10 Chlorophyll content (mg g⁻¹)

The total chlorophyll content in the leaves of carrot was extracted in 80% acetone and absorption at 663 nm and 645 nm are read in a spectrophotometer. Using the absorption coefficients, the amounts of chlorophyll was calculated as suggested by Ranganna (1986).

3.9.11 Nitrogen content (%)

Nitrogen content in the plant samples of carrot was estimated by Microkjeldhal method (AOAC, 1969) on dry weight basis.

3.9.12 Phosphorus and Potassium contents (%)

Phosphorus and Potassium contents were determined in the tri-acid extracts after digesting the plant material with tri-acid mixture 9:2:1 (HNO_3 : H_2SO_4 ; HClO_4).

The phosphorus content in the plant digest was determined by Vanado Molybdophosphoric yellow colour method using Klett Summer Sen Photo Electro Calorimeter and potassium content was determined with Elico-Flame Photometer (Piper, 1966).

3.9.13 N, P and K uptake (kg ha^{-1})

The uptake of N, P and K by carrot was calculated by using the following formula

$$\text{Uptake of nutrients} = \frac{\text{Total dry matter (kg ha}^{-1}\text{)} \times \% \text{ of nutrient content}}{100}$$

(kg ha^{-1})

3.10 PHYSICO-CHEMICAL PROPERTIES OF SOIL

3.10.1 Mechanical analysis

The per cent composition of soil components i.e., sand (coarse and fine) silt and clay were carried out by Bouyoucos Hydrometer as described by Piper (1950) and given in Table 1.

3.10.2 Soil pH

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

3.10.3 Electrical conductivity (dS m^{-1})

The soil EC was determined in the extract of soil and water suspension (1:2.5) with the help of solubility, following the method given by U.S. Salinity laboratory (1954).

3.10.4 Organic carbon

The soil organic carbon was determined by Walkely and Black's Method (1934) as described by Piper (1950).

3.10.5 Available nitrogen (kg N ha^{-1})

The soil available nitrogen was determined by alkaline permanganate method as described by Subbaiah and Asija (1956).

3.10.6 Available phosphorus ($\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$)

The soil available phosphorus (P_2O_5) was determined by Olsen's method (1954), using 0.5 M NaHCO_3 of pH 8.5 as given by Muhr *et al.* (1965).

3.10.7 Available potassium ($\text{kg K}_2\text{O ha}^{-1}$)

From soil complex potassium was extracted with neutral normal ammonium acetate and the quantity was determined using a Flame Photometer of Elico Model-22A (Muhr *et al.*, 1965).

3.11 ECONOMICS

3.11.1 B : C Ratio

Based on the gross and net returns from each treatment, the Benefit-Cost ratio (B:C ratio) was calculated by the procedure suggested by Reddy and Korwar (1985).

3.11.2 Income Equivalent Ratio (IER)

The Income Equivalent Ratio (IER) was calculated as suggested by Rao and Coe (1992) as:

$$\text{IER} = \frac{C_i}{C_s} + \frac{T_i}{T_s}$$

Where,

C_i = Income from crop under intercropping

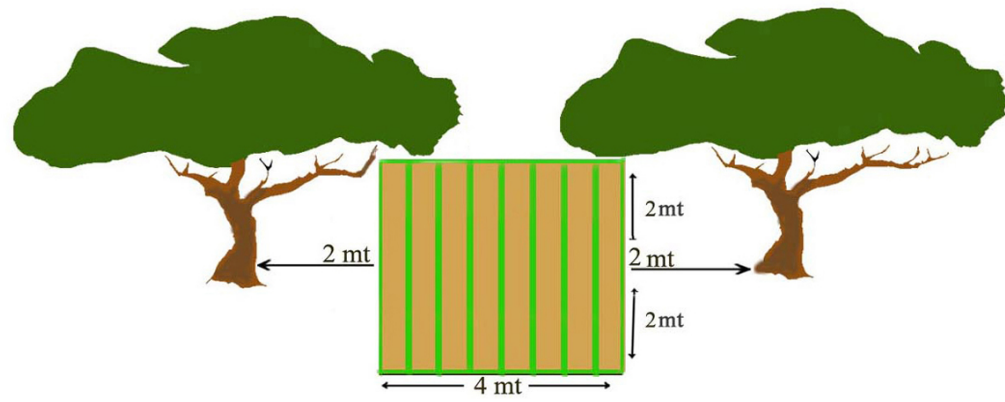
C_s = Income from crop under sole cropping

T_i = Income from tree under intercropping

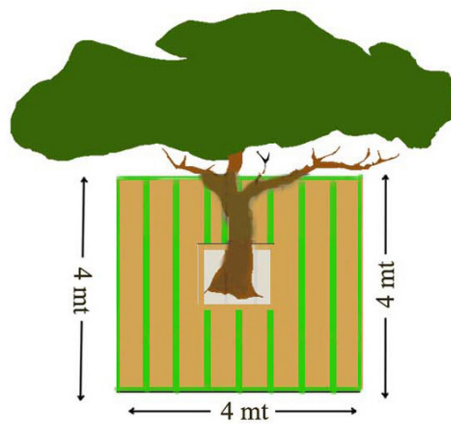
T_s = Income from tree under sole cropping

3.12 STATISTICAL ANALYSIS

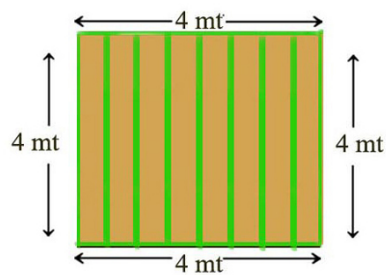
The data were subjected to statistical analysis, following the method given by Panse and Sukhatme (1967) with the help of DCM Completed.



Inter cropping



Under Planting



Sole cropping

Fig.2: Layout of individual plat under different cropping systems

CHAPTER -IV

RESULTS

The effect of different INM practices on carrot under various cropping situations in ber based system with respect to plant growth, yield, quality, changes in microclimatic and physiological parameters and productivity were studied. Besides, the effects of INM practices of carrot on yield, quality and productivity of ber were also studied. The results of the present investigations of the above aspect are presented hereunder.

4.1 PERFORMANCE OF CARROT

4.1.1 Plant height (cm)

The data on plant height of carrot under different cropping systems and INM practices at different stages of crop growth are presented in Table 3 and the trends are depicted in Fig. 3.

At 20 DAS significant differences were observed in plant height of carrot under different cropping systems, maximum plant height (12.28) was recorded in underplanted carrot followed by intercropped carrot (11.50) and the least in sole crop (10.70). Among different INM practices, neem cake in combination with half the recommended dose of NPK treatment recorded highest plant height of 12.54 followed by castor cake in combination with half the recommended dose of NPK (12.42) and full recommended dose of NPK (12.14) which were at par but significantly superior to all other treatments. Vermicompost in combination with half

the recommended dose of NPK treatment recorded significantly higher plant height (11.20) over half recommended dose NPK only (10.07).

At 40 DAS also the plant height of carrot differed significantly under different cropping systems and the trend was similar to that at 20 DAS i.e. maximum height was recorded in underplanted carrot (28.81) followed by intercropped carrot (26.29) and least was in sole carrot (25.02). Among the different sub treatments (INM practices), vermicompost in combination with half the recommended dose of NPK recorded highest plant height (27.57) followed by neem cake in combination with half the recommended dose of NPK (27.14), castor cake in combination with half the recommended dose of NPK (26.85) and full recommended dose of NPK only (26.82) which were at par but superior over half recommended dose of NPK only.

At 60 DAS also the trend in plant height of carrot in respect of cropping system was similar to that observed at 20 and 40 DAS. Among the different INM practices, neem cake in combination with half the recommended dose of NPK treatment recorded significantly highest (35.38) and the least in half recommended dose of NPK only (29.90). The other treatments were at par.

At 80 DAS also significant differences in plant height of carrot were recorded in respect of cropping system and the trend was similar to that at 20, 40 and 60 DAS. Among the different INM practices the

maximum plant height was recorded with neem cake in combination with half the recommended dose of NPK (37.79) followed by castor cake in combination with half the recommended dose of NPK (36.51) which were at par but neem cake treatment was significantly superior over other treatments. Significantly lowest plant height (31.68) was recorded with half the recommended dose of NPK compared to all other treatments.

The interaction between cropping systems and INM practices was not significant with respect to plant height of carrot at any stage of crop growth i.e. 20, 40, 60 and 80 DAS.

4.1.2 Root length (cm)

The data on root length of carrot under different cropping systems and INM practices at different stages of crop growth are presented in Table 4 and the trends are depicted in Fig. 4.

At 20 DAS the root length of carrot was maximum in sole crop (8.39) followed by intercrop (8.12) which were at par but superior over underplanted carrot (7.06). Among the different INM practices neem cake in combination with half the recommended dose of NPK and full recommended dose NPK recorded highest root length (8.85) followed by vermicompost in combination with half the recommended dose of NPK (7.89) and castor cake in combination with half the recommended dose of NPK (7.87) which were at par. Farm yard manure in combination with

half the recommended dose of NPK (6.62) recorded significantly lower root length.

At 40 DAS significantly highest root length of carrot was recorded in sole crop (10.99) over intercrop (8.69) and underplanted crop (8.13) which were at par. Among the different INM practices neem cake in combination with half the recommended dose of NPK recorded maximum root length (10.10) followed by FYM in combination with half the recommended dose of NPK (9.68). Vermicompost in combination with half the recommended dose of NPK (9.60) and full recommended dose of NPK only (9.58) which were at par. Significantly lowest root length was recorded with half the recommended dose of NPK only (7.71).

At 60 DAS also sole crop recorded maximum root length (14.38) followed by intercrop (12.98) which were at par but significantly higher over underplanted carrot (10.15). Among the INM practices neem cake in combination with half the recommended dose of NPK recorded maximum root length (13.89) followed by FYM in combination with half the recommended dose of NPK (13.45) which were at par but superior over castor cake (11.05) and half recommended dose of NPK only (10.54).

At 80 DAS the trend in root length of carrot in respect to cropping situations was similar to that observed at 60 DAS in all respects. Among the INM practices maximum root length was recorded in neem cake in combination with half the recommended dose of NPK (14.71) followed

by full recommended dose of NPK (14.04), vermicompost in combination with half the recommended dose of NPK (14.03) and FYM in combination with half the recommended dose of NPK (13.88) which were at par but significantly higher over half the recommended dose of NPK only (11.71).

The interaction between cropping systems and INM practices on root length of carrot had no significant effect at any stage of crop growth i.e. 20, 40, 60 and 80 DAS.

4.1.3 Root girth (cm)

The data pertaining to root girth of carrot under different cropping systems and INM practices at different stages of crop growth are presented in Table 4 and the trends are depicted in Fig. 4.

At 20 DAS significantly highest root girth was recorded in sole carrot (1.47) followed by intercropped carrot (1.25) and underplanted carrot (1.19) which were at par. Among the different INM practices castor cake in combination with half the recommended dose of NPK recorded significantly highest root girth (1.52) followed by full recommended dose NPK (1.34) and the least with half the recommended dose of NPK only (1.17) and vermicompost in combination with half the recommended dose of NPK (1.22).

At 40 DAS also significantly highest root girth was recorded in sole crop (4.70) followed by intercrop (3.23) and least in underplanted

carrot (2.94). Among different INM practices, the highest root girth was recorded with castor cake in combination with half the recommended dose of NPK (4.21) followed by other treatments which were at par, except half the recommended dose NPK only (2.92) which recorded the lowest root girth.

At 60 DAS the trend in root girth of carrot with respect to cropping systems was similar to that at 20 DAS i.e. maximum root girth was recorded in sole carrot (7.55) followed by intercropped carrot (4.85) and underplanted carrot (4.67) which were at par. Among the different INM practices maximum root girth was recorded with castor cake in combination with half the recommended dose of NPK (6.15) followed by full recommended dose NPK (5.92) which were at par but significantly superior over other treatments and the least with half recommended dose NPK only (5.15).

At 80 DAS significantly highest root girth of carrot was recorded in sole crop (8.72) followed by intercrop (8.20) and least in under planted carrot (7.74). Among the different INM practices castor cake in combination with half the recommended dose of NPK recorded maximum root girth (8.92) followed by FYM in combination with half the recommended dose of NPK (8.60), and from recommended dose NPK (8.32) which were at par but superior over vermicompost in combination with half the recommended dose of NPK (7.73) and half the recommended dose of NPK only (7.55).

The interaction between cropping systems and INM practices on root girth of carrot had no significant effect at any stage of crop growth i.e. 20, 40, 60 and 80 DAS.

4.1.4 Fresh weight of root (g plant⁻¹)

The data on fresh weight of carrot roots under different cropping systems and INM practices at different stages of crop growth are presented in Table 5 and the trends are depicted in Fig. 5.

At 20 DAS significant differences were observed in fresh weight of root under different cropping systems, the highest was with sole crop (0.56) followed by intercrop (0.37) and least in underplanted carrot (0.31). Among the different INM practices, maximum root weight was recorded with castor cake in combination with half the recommended dose of NPK (0.48) treatment followed by neem cake in combination with half the recommended dose of NPK (0.46) which were at par but significantly higher over other treatments and the least with half the recommended dose of NPK only (0.34).

The interaction between cropping system and INM practices was not significant with respect to fresh weight of root in case of underplanted crop. However, under intercropping, neem cake and castor cake in combination with half the recommended dose of NPK recorded significantly higher fresh weight of root compared to other INM practices, while under sole cropping with castor cake in combination with

half the recommended dose of NPK recorded significantly highest fresh weight of root (0.69) over other INM practices followed by neem cake (0.69) and vermicompost (0.57) treatment.

At 40 DAS significantly highest fresh weight of root (6.44) was recorded in sole crop followed by intercropped (4.77) and underplanted carrot (4.60) which differed significantly with each other. Among the INM practices significantly higher fresh weight of carrot was recorded with castor cake in combination with half the recommended dose of NPK (5.69) over other treatments followed by neem cake in combination with half the recommended dose of NPK (5.51), full recommended dose of NPK (5.43), vermicompost (5.39) which were at par but superior to FYM in combination with half the recommended dose of NPK (5.28) and least with half recommended dose NPK only (4.31). The interaction between the cropping systems and INM practices was not significant.

At 60 DAS also the fresh weight of carrot root was significantly higher with sole crop (20.24) and the trend was similar with respect to other cropping systems as observed at 20 DAS. Among the INM practices the maximum fresh weight of root was observed with castor cake in combination with half the recommended dose of NPK (17.63) followed by neem cake in combination with half the recommended dose of NPK (16.85) which were at par but significantly superior over other treatments, the least root weight was recorded with half recommended dose of NPK only (13.40).

At 80 DAS significantly highest fresh weight of root was recorded in sole crop (51.64), followed by intercrop (41.56) and under planted carrot (40.48) which were at par.

Among INM practices maximum fresh weight of root was observed with castor cake in combination with half the recommended dose of NPK (48.83) followed by neem cake in combination with half the recommended dose of NPK (48.82), vermicompost in combination with half recommended dose NPK (45.81), FYM in combination with half the recommended dose of NPK (44.32) and full recommended dose NPK (43.73) which were at par but significantly higher over half the recommended dose of NPK only (35.93).

The interaction between cropping systems and INM practices on fresh weight of root of carrot had no significant effect at 3 stages of crop growth i.e. 40, 60 and 80 DAS.

4.1.5 Dry weight of root (g plant⁻¹)

The data on dry weight of carrot roots under different cropping systems and INM practices at different stages of crop growth are presented in Table 5 and the trends are depicted in Fig. 5.

At 20 DAS significantly highest dry weight of root was recorded in sole crop (0.13) followed by intercrop (0.06) and underplanted crop (0.04) which were at par. Among the INM practices castor cake in combination with half the recommended dose of NPK recorded maximum

dry weight of roots (0.09) but on par with other treatments except half the recommended dose of NPK only (0.06), which recorded lowest dry weight of roots. The interaction between cropping systems and INM practices was not significant in case of under planted and intercropped carrot but compared to these cropping situations, INM practices under sole crop recorded significantly higher dry weight of carrot.

At 40 DAS, maximum dry weight of root was recorded in sole crop (1.55) followed by intercrop (1.47) which were at par and the least in under planted carrot (1.37). Among different INM practices, maximum dry weight of root was recorded with castor cake in combination with half the recommended dose of NPK (1.59) followed by neem cake in combination with half the recommended dose of NPK (1.54) which were at par and the least with half the recommended dose of NPK only (1.27).

At 60 DAS also highest dry weight of root was observed in sole crop (3.28) followed by intercrop (2.79) and the least in underplanted carrot (2.31). Among different INM practices maximum dry weight of root was recorded with castor cake in combination with half the recommended dose of NPK (3.09) which were at par with neem cake in combination with half the recommended dose of NPK (3.01) and full recommended dose of NPK (2.93) but significantly higher compared to other INM practices.

At 80 DAS also the dry weight of carrot differed significantly under different cropping systems and the trend was similar to that observed at 60 DAS. Among the INM practices maximum dry weight of root was recorded with castor cake in combination with half the recommended dose of NPK (5.19), followed by neem cake in combination with half the recommended dose of NPK (5.07) and full recommended dose of NPK (5.01) which were at par, and the least with half the recommended dose of NPK only (4.35).

The interaction between cropping systems and INM practices on dry weight of carrot root had no significant effect at 40, 60 and 80 DAS.

4.1.6 Root yield (t ha⁻¹)

The data on root yield of carrot under different cropping systems and INM practices are presented in Table 6 and the trends are depicted in Fig. 6. The root yield of carrot differed significantly under different cropping situations, the highest being in sole cropping (19.15) followed by intercropping (12.63) and the least in underplanted crop (10.02). Among the INM practices significantly highest root yield was obtained with castor cake in combination with half the recommended dose of NPK treatment (15.86) followed by full recommended dose of NPK (14.87), neem cake in combination with half the recommended dose of NPK (14.71) and vermicompost in combination with half the recommended

dose of NPK (14.14) which were at par and the least with half the recommended dose of NPK only (10.10).

The interaction between cropping situations and INM practices revealed that irrespective of cropping system half recommended dose of NPK recorded significantly lowest root yield compared to other INM practices except in underplanted crop, where vermicompost in combination with half the recommended dose of NPK also recorded lower yields than other treatments.

4.1.7 Shoot yield (t ha^{-1})

The data on shoot yield of carrot under different cropping systems and INM practices are presented in Table 6 and the trends depicted in Fig. 6.

The shoot yield of carrot under different cropping systems did not vary significantly. Among the different INM practices the maximum shoot yield was recorded with full recommended dose of NPK (19.05) followed by neem cake in combination with half the recommended dose of NPK (18.78), castor cake in combination with half the recommended dose of NPK (18.73), FYM in combination with half the recommended dose of NPK (18.14) and vermicompost in combination with half the recommended dose of NPK (17.21) which were at par but significantly higher than half the recommended dose of NPK only (14.19). The

interaction between cropping systems and INM practices was not significant.

4.1.8 Shoot-root ratio

The data in shoot-root ratio of carrot under different cropping systems and INM practices are presented in Table 6.

The shoot-root ratio differed significantly under different cropping systems, the highest being in under planted carrot (1.70) followed by intercrop (1.40) and the least in sole crop (1.01). Among the different INM practices the maximum shoot-root ratio was recorded with neem cake in combination with half the recommended dose of NPK and half the recommended dose of NPK only (1.47), followed by FYM in combination with half the recommended dose of NPK (1.41) and full recommended dose of NPK (1.38) which were at par. Vermicompost in combination with half the recommended dose of NPK (1.31) and castor cake in combination with half the recommended dose of NPK (1.25) were at par but recorded significantly lower shoot-root ratio than other treatments. The interaction between cropping situations and INM practices was not significant.

4.1.9 Carotene content (mg/100 g sample)

The data on carotene content of carrot roots under different cropping systems and INM practices are presented in Table 7 and the trends depicted in Fig. 7.

Significantly highest carotene content was recorded in sole carrot (4.22) followed by intercropped carrot (4.00) and underplanted carrot (3.96) which were at par. Among the different INM practices, neem cake in combination with half the recommended dose of NPK recorded significantly highest carotene content (4.22) followed by vermicompost in combination with half the recommended dose of NPK (4.09), castor cake in combination with half the recommended dose of NPK (4.08), full recommended dose of NPK (4.05) and FYM in combination with half the recommended dose of NPK (4.00) which were at par and significantly lowest carotene content was recorded with half the recommended dose of NPK only (3.82). The interaction between cropping systems and INM practices was not significant.

4.1.10 Total soluble solids (° Brix)

The data on Total Soluble Solids (TSS) content of carrot roots under different cropping systems and INM practices are presented in table 7 and trends depicted in Fig. 8.

The highest TSS content was in sole carrot (13.09) followed by intercrop (13.37) and the least in under planted carrot (11.99). Among the different INM practices, neem cake in combination with half the recommended dose of NPK recorded highest TSS content (12.81) but on par with castor cake in combination with half the recommended dose of NPK (12.53). The other treatments recorded lower TSS which were on

par with half the recommended dose of NPK only (12.29). The interaction between cropping situations and INM practices was also not significant.

4.1.11 Reducing sugars (%)

The data on reducing sugars of carrot under different cropping systems and INM practices are presented in Table 7 and the trends depicted in Fig. 9.

The reducing sugar content of carrot root under different cropping systems differed significantly; highest being in sole carrot (4.00) followed by intercrop (3.90) and least in underplanted carrot (3.75). Among the different INM practices, neem cake in combination with half the recommended dose of NPK recorded maximum reducing sugar content (3.98) followed by castor cake in combination with half the recommended dose of NPK (3.97) and full recommended dose of NPK (3.95) but significantly superior over half the recommended dose of NPK (3.75). The interaction between cropping systems and INM practices was not significant.

4.1.12 Non-reducing sugars (%)

The data on non-reducing sugar content of carrot under different cropping systems and INM practices are presented in Table 7 and the trends depicted in Fig. 9.

The non-reducing sugar content of carrot roots did not differ significantly under different cropping situations and INM practices.

4.1.13 Total sugars (%)

The data on total sugar content of carrot roots under different cropping systems and INM practices are presented in Table 7 and the trends depicted in Fig. 9.

The total sugar content of carrot roots significantly differed under different cropping systems. The maximum total sugar content was recorded in sole carrot (8.19) followed by intercropped carrot (8.02) which were at par but sole crop recorded significantly higher total sugar content compared to under planted carrot (7.81). The different INM practices and their interaction with cropping situations did not differ significantly in respect to total sugar content of carrot roots.

4.1.14 Total chlorophyll content (mg 100g⁻¹)

The total chlorophyll content of carrot leaves under different cropping systems and INM practices are presented in Table 8 .

The total chlorophyll content of carrot leaves significantly differed under different cropping systems, the highest chlorophyll content was recorded in underplanted (1.56) followed by intercropped carrot (1.37) and sole carrot (1.26) which were at par. The INM practices and their interaction with cropping systems was not significant in affecting the chlorophyll content of carrot leaves.

4.1.15 Nitrogen content (%)

The data pertaining to nitrogen content in plant sample of carrot under different cropping systems and INM practices are presented in Table 8 and the trends depicted in Fig. 10.

The nitrogen content of carrot significantly differed under different cropping systems, maximum being in sole crop (1.86) followed by intercrop (1.84) which were at par but significantly higher over under planted carrot (1.71). Among the different INM practices, significantly highest nitrogen content was recorded with full recommended dose of NPK (1.92) followed by castor cake in combination with half the recommended dose of NPK (1.86), neem cake in combination with half the recommended dose of NPK (1.82), vermicompost in combination with half the recommended dose of NPK (1.79) and FYM in combination with half the recommended dose of NPK (1.74) and least in half the recommended dose of NPK only (1.66). The interaction between cropping systems and INM practices revealed that full dose of NPK recorded highest N content both under sole crop and underplanted crop and least with half the recommended dose of NPK only irrespective of the cropping systems.

4.1.16 Phosphorus content (%)

The data pertaining to phosphorus content in plant samples of carrot under different cropping systems and INM practices are presented in Table 8 and the trends depicted in Fig. 10.

Significantly highest phosphorus content was recorded both in sole crop and intercrop (0.29) compared to underplanted crop (0.24). Among the different INM practices, phosphorus content ranged between 0.24 to 0.30 and significantly highest was recorded with castor cake in combination with half the recommended dose of NPK (0.30) and least was recorded with half the recommended dose of NPK only (0.24). The other treatments did not differ with each other in respect to P content.

The interaction between cropping systems and INM practices also showed significant differences among treatments. Castor cake in combination with half the recommended dose of NPK recorded significantly higher P content irrespective of the cropping system, while half the recommended dose of NPK alone treatment recorded least P content in all the cropping system tried.

4.1.17 Potassium content (%)

The data pertaining to potassium content in plant sample of carrot under different cropping systems and INM practices are presented in Table 8 and the trends depicted in Fig. 10.

The potassium content of carrot was significantly highest in sole crop (2.91) followed by intercrop (2.71) and least in the underplanted carrot (2.52). Among the different INM practices maximum potassium content was recorded with castor cake in combination with half the recommended dose of NPK (2.89) followed by full recommended dose of NPK (2.87) which were at par and the lowest with half the recommended dose of NPK only (2.25).

The interaction between cropping systems and INM practices revealed that half the recommended dose of NPK recorded significantly lowest K content irrespective of cropping systems.

4.1.18 Nitrogen uptake (kg ha^{-1})

The data pertaining to nitrogen uptake by carrot crop under different cropping systems and INM practices are presented in Table 9 and the trends depicted in Fig. 11.

Nitrogen uptake by carrot crop significantly differed under different cropping systems, the highest was in sole crop (36.59) followed by intercrop (29.61) and least in underplanted carrot (17.46). Among the different INM practices, maximum nitrogen uptake was recorded with full recommended dose of NPK (30.98) followed by castor cake in combination with half the recommended dose of NPK (29.95) which were at par and least was recorded with half the recommended dose of NPK

only (22.69). The interaction between cropping systems and INM practices was not significant.

4.1.19 Phosphorus uptake (kg ha^{-1})

The data on phosphorus uptake by carrot crop under different cropping systems and INM practices are presented in Table 9 and the trends depicted in Fig. 11.

Significantly highest P uptake was recorded in sole crop (6.44) followed by intercrop (4.80) and least in underplanted carrot (2.30). Among the different INM practices maximum P uptake was with castor cake in combination with half the recommended dose of NPK (4.99) followed by FYM in combination with half the recommended dose of NPK (4.85), full recommended dose of NPK (4.83) and neem cake in combination with half the recommended dose of NPK (4.75) which were at par. Significantly lowest P uptake was with half the recommended dose of NPK only (3.38). The interaction between cropping systems and INM practices was not significant.

4.1.20 Potassium uptake (kg ha^{-1})

The data pertaining to uptake by carrot crop under different cropping systems and INM practices are presented in Table 9 and the trends depicted in Fig. 11.

Significantly highest potassium uptake was recorded in sole crop (62.99) followed by intercrop (42.89) and least in underplanted carrot

(22.07). Among the different INM practices maximum K uptake was recorded with castor cake in combination with half the recommended dose of NPK (48.49), followed by full recommended dose of NPK (46.66) and neem cake in combination with half the recommended dose of NPK (46.49) which were at par. Significantly lowest K uptake was recorded with half the recommended dose of NPK only (31.72). The interaction between cropping systems and INM practices showed significant differences among different treatments. Maximum K uptake was recorded with castor cake (70.07) followed by full recommended dose of NPK (67.87) and neem cake (67.79) in sole crop and least with half recommended dose NPK only (17.07) in under planted carrot.

4.2 DIURNAL VARIATIONS IN MICROCLIMATIC AND PHYSIOLOGICAL PARAMETERS

4.2.1 Diurnal variations in PAR ($\mu \text{ mol s}^{-1} \text{ m}^{-2}$)

The data on diurnal variation in quantum (PAR) on top of carrot canopy under different cropping systems and INM practices are presented in Table 10 and the trend depicted in Fig. 12.

At 8.00 hrs significantly highest Photosynthetically Active Radiation (PAR) was recorded in sole crop (1089) followed by intercrop (767.44) and least in underplanted carrot (469.39). Different INM practices and their interaction with cropping systems did not differ significantly with each other.

At 12.00 hrs and 16.00 hrs the trend in available PAR was similar to that at 8.00 hrs with respect of cropping systems, INM practices and their interaction with cropping systems.

4.2.2 Leaf temperature (° C)

The data pertaining to diurnal variations in leaf temperature of carrot on top of the crop canopy under different cropping systems and INM practices are presented in Table 11 and the trends depicted in Fig. 12.

At 8.00 hrs significantly higher leaf temperature (27.09) was recorded in sole crop compared to under planted crop (25.32) but on par with intercropped carrot (26.30). There were no significant differences among the INM practices with regard to leaf temperature. The interaction between cropping systems and INM practices was also not significant.

At 12.00 hrs significantly highest leaf temperature was recorded in sole carrot (32.50) followed by intercropped carrot (31.09) which were at par with underplanted carrot (30.35). The INM practices and their interaction with cropping systems had no significant effect on the leaf temperature.

At 16.00 hrs the trend in leaf temperature on the top of carrot canopy was similar to that of 8.00 hrs in all respects.

4.2.3 Relative humidity (%)

The data on diurnal variation in relative humidity within the crop canopy of carrot under different cropping systems and INM practices are presented in Table 11 and the trends depicted in Fig.12.

At 8.00 hrs significantly higher relative humidity was recorded in under planted crop (36.20) over sole crop (32.06) but at par with intercrop (34.03). The INM practices and their interaction with cropping systems had no significant effect on the relative humidity of carrot crop canopy.

At 12.00 hrs significantly highest relative humidity was recorded in under planted crop (32.75) followed by intercropped carrot (31.53) and least in sole carrot (30.52). Among the INM practices maximum relative humidity was recorded in crop supplied with full recommended dose of NPK (32.21) followed by FYM in combination with half the recommended dose of NPK (31.91) and neem cake in combination with half the recommended dose of NPK (31.89) which were at par but significantly higher over half recommended dose of NPK only (31.19).

At 16.00 hrs significantly highest relative humidity was recorded in under planted crop (30.93) followed by intercrop (30.13) and least in sole carrot. The INM practices and their interaction had no significant effect on relative humidity of carrot crop.

4.2.4 Transpiration rate

The data pertaining to diurnal variation in transpiration rate of carrot crop under different cropping systems and INM practices are presented in Table 12 and the trends depicted in Fig. 12.

At 8.00 hrs significantly highest rate of transpiration was recorded in sole crop (16.24) followed by intercropped carrot (14.22) and least in under planted crop (13.33). Among the different INM practices significantly higher rate of transpiration was recorded with full recommended dose NPK (14.75) followed by in combination with half the recommended dose of NPK (14.69) compared to vermicompost in combination with half the recommended dose of NPK (14.50), castor cake in combination with half the recommended dose of NPK and FYM in combination with half the recommended dose of NPK which were at par.

At 12.00 hrs the trend in rate of transpiration of carrot crop with respect to cropping system was similar to that observed at 8.00 hrs. However, the different INM practices and their interactions with cropping systems had no significant effect on transpiration rate.

At 16 hrs also the trend in rate of transpiration of carrot crop with respect to cropping systems, INM practices and their interactions was similar in all respects to that observed at 12.00 hrs.

4.2.5 Stomatal diffusive resistance

The data on diurnal variation in stomatal diffusive resistance of carrot are presented in Table 12 and the trends depicted in Fig. 12.

At 8.00 hrs maximum diffusive resistance was recorded in under planted crop (0.37) followed by intercrop (0.33) and least in sole crop (0.26). Different INM practices and their interaction with cropping system had no significant effect on stomata diffusive resistance.

At 12.00 hrs the trend in standard diffusive resistance with respect to cropping system was similar to that observed at 8.00 hrs, but among the different INM practices maximum diffused resistance was recorded in carrot crop with neem cake (0.39), FYM (0.39) which were at par. Minimum stomatal diffusive resistance was recorded with full recommended dose of NPK (0.36). The interaction between cropping systems and INM practices were not significant.

At 16.00 hrs the trend in stomatal diffusive resistance of carrot with regard to cropping systems was similar to that observed at 12.00 hrs, but with respect of different INM practices it was similar to that observed at 8.00 hrs in all aspects.

4.3 EFFECT OF INM PRACTICES OF CARROT ON BER

4.3.1 Fruit yield (kg plant⁻¹ and t ha⁻¹)

The data on fruit yield of ber under different cropping systems and INM practices of associated carrot crop are presented in Table 13 and the trends depicted in Fig. 13.

Maximum fruit yield was recorded in ber in which carrot was under planted with neem cake in combination with half the recommended dose of NPK (38.30) followed by vermicompost in combination with half the recommended dose of NPK (36.40) and full recommended dose of NPK (35.40) which were at par and minimum was recorded in ber intercropped with carrot with half recommended dose of NPK (29.00).

The trend in fruit yield of ber t ha⁻¹ was similar to that of fruit yield kg plant⁻¹ with respect to treatment effect.

4.3.2 Average fruit weight (g)

The data pertaining to average fruit weight of ber under different cropping systems and INM practices of associated carrot are presented in Table 13.

The average fruit weight of ber under different treatments ranged from 19.43 to 21.64. The average fruit weight did not differ significantly among different treatments.

4.3.3 Reducing sugars (%)

The data on reducing sugars of ber under different cropping systems and INM practices of associated carrot crop are presented in Table 14.

From the perusal of the data it is seen that, there was no significant difference among the treatments with respect to reducing sugars content of ber fruits. However, the reducing sugars ranged from 2.87 to 3.23. The maximum reducing sugar content was recorded in ber which was underplanted with carrot with neem cake in combination with half the recommended dose of NPK (3.23) and minimum in ber intercropped with carrot with half recommended dose of NPK (2.87).

4.3.4 Non-reducing sugars (%)

The data on non-reducing sugars of ber fruit under different cropping systems and INM practices of associated carrot crop are presented in Table 14.

The non-reducing sugar content of ber fruit under different treatments ranged between 4.50 to 5.00. The non-reducing sugars did not differ significantly among different treatments.

4.3.5 Total soluble solids (°Brix)

The data on Total Soluble Solids (TSS) content of ber fruit under different cropping systems and INM practices of associated carrot crop are presented in Table 14.

No significant differences among the treatments were noticed with respect to TSS content of ber fruits. The maximum TSS content was recorded in ber underplanted with carrot with full recommended dose of NPK (15.07) and minimum was recorded when ber was intercropped with carrot with either half recommended dose of NPK or full recommended dose of NPK (14.57).

4.3.6 Acidity (%)

The data on acidity of ber fruit under different treatments are presented in Table 14.

The acidity in ber fruit under different treatments though not significant ranged from 0.28 to 0.32, maximum being in ber intercropped with carrot with half recommended dose of NPK and least with vermicompost with half recommended dose of NPK.

4.3.7 Nitrogen content (%)

The data on nitrogen content of ber leaves in different treatments are presented in Table 15.

No significant differences among different treatments was noticed with respect to nitrogen content in ber leaves. However, maximum nitrogen content was recorded when ber was under planted with carrot in the castor cake in combination with half the recommended dose of NPK (2.04) and minimum when underplanted with carrot FYM in combination with half the recommended dose of NPK (1.99).

4.3.8 Phosphorus content (%)

The data on phosphorus content in ber leaves under different treatments are presented in Table 15.

The phosphorus content in ber leaves under different treatments ranged from 0.11 to 0.16. However, the phosphorus content did not differ significantly among different treatments.

4.3.9 Potassium content (%)

The data on potassium content in ber leaves under different treatments are presented in Table 15.

From the data presented, it is seen that the treatments did not differ significantly with respect to K content in ber leaves, though minimum K content of 1.18 was recorded in ber underplanted with carrot and applied with neem cake or castor cake and recommended dose NPK. The minimum was with half the recommended dose of NPK treatment (1.12).

4.4 ECONOMIC EVALUATION OF BER BASED CROPPING SYSTEM WITH CARROT UNDER DIFFERENT INM PRACTICES

4.4.1 Gross monetary returns (Rs. ha⁻¹)

The data on mean monetary gross returns from ber based cropping system with carrot under different INM practices are presented in Table 16 and the trends depicted in Fig. 14.

From the data presented, it is seen that maximum gross monetary returns (67,833) were obtained from intercropping of carrot in ber with

the application of castor cake in combination with half the recommended dose of NPK. The gross monetary returns were, in general, higher with intercropping and underplanting of carrot in ber compared to sole carrot and sole ber, irrespective of the INM practices adopted. Different INM practices did not differ significantly with each other in increasing the gross monetary returns and were at par except half the recommended dose of NPK treatment which recorded the least returns in all the cropping systems. Sole ber recorded the least gross monetary returns (23,000).

4.4.2 Net monetary returns (Rs. ha⁻¹)

The data on net monetary returns from ber based cropping system with carrot under different INM practices are presented in Table 16 and the trends depicted in Fig. 14.

From the data, it is seen that significantly higher net monetary returns were obtained when carrot was grown as sole crop with full recommended dose of NPK followed by sole carrot with castor cake in combination with half the recommended dose of NPK (38,672) and the least when carrot was underplanted in ber with vermicompost in combination with half the recommended dose of NPK (10,718). However, among cropping systems, sole ber recorded lowest net returns (9,346), while among the INM practices, application of vermicompost in combination with half the recommended dose of NPK to carrot recorded lower net returns compared to other practices irrespective of the cropping system.

4.4.3 Benefit-cost ratio (B:C ratio)

The data on benefit-cost ratio (B:C ratio) of ber based cropping system with carrot as affected by different cropping systems and INM practices are presented in Table 17.

From the data, it is seen that the B:C ratio were found to be greater than unity in all treatments, indicating fairly high returns on every rupee invested. However, these ratios were higher with sole carrot compared to intercropped or underplanted carrot with ber. Among the different INM practices full recommended dose of NPK treatment recorded higher B:C ratio in all situations when carrot was underplanted in ber (1.97) or intercropped with ber (2.17) and under sole cropping (3.84) while vermicompost in combination with half the recommended dose of NPK recorded relatively lower values in all the cropping systems.

4.4.4 Income Equivalent Ratio (IER)

The data on income equivalent ratio in ber based cropping system with carrot as affected by cropping system and INM practices are presented in Table 17.

From the data, it is seen that the IER values were greater than unity, indicating advantage of either underplanting or intercropping of carrot with ber over its sole cropping.

Maximum IER values of 1.82 was recorded when carrot was under planted in ber with neem cake in combination with half the recommended

dose of NPK and castor cake in combination with half the recommended dose of NPK (1.73) and the least in underplanted carrot with FYM in combination with half the recommended dose of NPK (1.61).

Table 3 : Plant height of carrot as affected by cropping system and INM practices at different stages of crop growth

Treatments	Plant height (cm) (DAS)			
	20	40	60	80
<i>Cropping systems (Main treatments)</i>				
Under Planting (UP)	12.28	28.81	37.19	39.99
Inter Cropping (IC)	11.50	26.29	33.31	36.23
Sole Cropping (SC)	10.67	25.02	28.31	29.50
S.Ed.±	0.18	0.28	0.16	0.64
CD (at 5%)	0.51	0.78	0.44	1.79
<i>INM practices (Sub treatments)</i>				
Vermicompost+½ RD NPK (VC)	11.20	27.57	32.79	35.59
Neem Cake+½ RD NPK (NC)	12.54	27.14	35.38	37.79
Castor Cake+½ RD NPK (CC)	12.42	26.85	33.71	36.51
FYM+½ RD NPK (FYM)	10.53	26.40	32.43	34.59
½ RD NPK only (½ RD)	10.07	25.45	29.90	31.68
RD NPK (RD)	12.14	26.82	33.43	35.27
S.Ed.±	0.38	0.61	0.78	0.79
CD (at 5%)	0.78	1.24	1.59	1.62
<i>Interactions (Main x Sub)</i>				
UP x VC	12.30	29.30	37.47	40.47
UP x NC	13.13	29.77	40.13	42.50
UP x CC	13.53	29.60	38.43	41.17
UP x FYM	10.87	28.87	36.93	39.63
UP x ½ RD	10.87	26.47	33.03	36.57
UP x RD	13.03	28.86	37.17	39.60
IC x VC	10.97	27.03	33.43	36.53
IC x NC	12.63	26.00	35.63	39.60
IC x CC	12.87	26.50	34.40	38.13
IC x FYM	10.67	26.23	32.80	35.53
IC x ½ RD	9.76	25.40	29.80	32.27
IC x RD	12.10	26.60	33.80	35.33
SC x VC	10.33	26.37	27.47	29.77
SC x NC	11.87	25.67	30.37	31.27
SC x CC	10.87	24.47	28.30	30.23
SC x FYM	10.07	24.10	27.57	28.60
SC x ½ RD	9.57	24.50	26.87	26.23
SC x RD	11.30	25.00	29.33	30.90
S.Ed.±	0.66	1.06	1.35	1.55
CD (at 5%)	NS	NS	NS	NS

Table 4 : Root length and root girth of carrot as affected by cropping system and INM practices at different stages of crop growth

Treatments	Root length (cm)				Root girth (cm)			
	DAS				DAS			
	20	40	60	80	20	40	60	80
<i>Cropping systems (Main treatments)</i>								
Under Planting (UP)	7.06	8.13	10.15	12.13	1.19	2.94	4.67	7.74
Inter Cropping (IC)	8.12	8.69	12.98	13.97	1.25	3.23	4.85	8.20
Sole Cropping (SC)	8.39	10.99	14.38	14.68	1.47	4.70	7.55	8.72
S.Ed.±	0.16	0.22	0.74	0.38	0.06	0.06	0.12	0.15
CD (at 5%)	0.44	0.61	2.04	1.07	0.15	0.18	0.34	0.43
<i>INM practices (Sub treatments)</i>								
Vermicompost+½ RD NPK (VC)	7.89	9.60	13.40	14.03	1.22	3.53	5.56	7.73
Neem Cake+½ RD NPK (NC)	8.85	10.10	13.89	14.71	1.29	3.71	5.65	8.21
Castor Cake+½ RD NPK (CC)	7.87	8.98	11.05	13.18	1.52	4.21	6.15	8.92
FYM+½ RD NPK (FYM)	7.05	9.68	13.45	13.88	1.29	3.64	5.70	8.60
½ RD NPK only (½ RD)	6.62	7.71	10.54	11.71	1.17	2.92	5.15	7.55
RD NPK (RD)	8.85	9.58	12.70	14.04	1.34	3.74	5.92	8.32
S.Ed.±	0.53	0.35	0.53	0.46	0.06	0.17	0.12	0.32
CD (at 5%)	1.08	0.70	1.08	0.93	0.11	0.35	0.26	0.65
<i>Interactions (Main x Sub)</i>								
UP x VC	7.77	8.23	11.37	12.30	1.03	2.80	4.50	7.00
UP x NC	6.63	8.77	11.63	13.33	1.20	2.93	4.63	7.63
UP x CC	6.67	7.83	9.13	12.00	1.33	3.60	5.13	8.67
UP x FYM	6.93	8.40	10.40	12.27	1.20	3.10	4.73	8.30
UP x ½ RD	6.37	7.13	8.60	10.47	1.10	2.20	4.10	7.13
UP x RD	8.00	8.43	9.77	12.40	1.27	3.03	1.90	7.73
IC x VC	7.80	9.07	13.80	14.53	1.13	3.10	4.70	7.67
IC x NC	9.73	9.10	14.63	14.87	1.27	3.20	4.77	8.00
IC x CC	8.43	8.17	10.57	13.27	1.43	3.80	5.30	8.80
IC x FYM	6.97	9.27	14.53	14.03	1.27	2.97	4.93	8.60
IC x ½ RD	6.67	7.77	11.20	12.57	1.10	2.97	4.33	7.07
IC x RD	9.13	8.80	13.20	14.57	1.33	3.37	5.07	8.50
SC x VC	8.10	11.50	15.03	15.27	1.50	4.70	7.47	8.53
SC x NC	10.20	12.43	15.40	15.93	1.40	5.00	7.57	9.00
SC x CC	8.50	10.93	13.47	14.27	1.80	5.23	8.03	9.30
SC x FYM	7.27	11.37	15.43	15.33	1.40	4.87	7.43	8.90
SC x ½ RD	6.83	8.23	11.83	12.10	1.30	3.60	7.03	7.87
SC x RD	9.43	11.50	15.13	15.17	1.43	4.83	7.80	8.73
S.Ed.±	0.92	0.60	1.68	0.92	0.13	0.29	0.29	0.55
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS

Table 5 : Average fresh and dry weight (g plant⁻¹) of carrot root as affected by cropping system and INM practices at different stages of crop growth

Treatments	Fresh weight (cm)				Dry weight (cm)			
	DAS				DAS			
	20	40	60	80	20	40	60	80
<i>Cropping systems (Main treatments)</i>								
Under Planting (UP)	0.31	4.60	12.63	40.48	0.04	1.37	2.57	3.51
Inter Cropping (IC)	0.37	4.77	14.02	41.56	0.06	1.47	2.79	4.72
Sole Cropping (SC)	0.56	6.44	20.24	51.64	0.13	1.55	3.28	6.49
S.Ed.±	0.01	0.03	0.41	1.99	0.01	0.03	0.07	0.04
CD (at 5%)	0.03	0.09	1.14	5.52	0.02	0.09	0.21	0.12
<i>INM practices (Sub treatments)</i>								
Vermicompost+½ RD NPK (VC)	0.39	5.39	15.50	45.81	0.07	1.43	2.90	4.95
Neem Cake+½ RD NPK (NC)	0.46	5.51	16.85	48.82	0.08	1.54	3.01	5.07
Castor Cake+½ RD NPK (CC)	0.48	5.69	17.63	48.83	0.09	1.59	3.09	5.19
FYM+½ RD NPK (FYM)	0.39	5.28	15.03	44.23	0.08	1.46	2.79	4.87
½ RD NPK only (½ RD)	0.34	4.31	13.40	35.93	0.06	1.27	2.55	4.35
RD NPK (RD)	0.41	5.43	15.35	43.73	0.08	1.49	2.93	5.01
S.Ed.±	0.02	0.08	0.48	2.74	0.01	0.03	0.09	0.10
CD (at 5%)	0.04	0.16	0.98	5.60	0.02	0.07	0.18	0.20
<i>Interactions (Main x Sub)</i>								
UP x VC	0.31	4.71	12.40	42.63	0.04	1.36	2.60	3.60
UP x NC	0.35	4.81	13.80	45.23	0.05	1.40	2.67	3.60
UP x CC	0.34	5.04	14.30	46.40	0.05	1.42	2.80	3.77
UP x FYM	0.30	4.74	12.23	40.60	0.04	1.39	2.53	3.43
UP x ½ RD	0.27	3.54	10.77	28.77	0.03	1.25	2.23	3.07
UP x RD	0.32	4.73	12.30	39.23	0.05	1.41	2.60	3.60
IC x VC	0.32	4.92	13.57	43.27	0.06	1.42	2.77	4.80
IC x NC	0.42	5.03	15.53	46.00	0.06	1.58	2.97	5.03
IC x CC	0.42	5.21	16.30	47.60	0.07	1.63	3.03	5.00
IC x FYM	0.37	4.82	13.20	41.60	0.06	1.49	2.67	4.60
IC x ½ RD	0.31	3.78	12.00	30.67	0.04	1.26	2.40	4.03
IC x RD	0.38	4.87	13.50	40.53	0.06	1.45	2.90	4.83
SC x VC	0.57	6.56	20.53	51.53	0.11	1.51	3.33	6.47
SC x NC	0.61	6.69	21.23	55.23	0.14	1.63	3.40	6.57
SC x CC	0.69	6.83	22.30	52.50	0.16	1.73	3.43	6.80
SC x FYM	0.52	6.29	19.67	50.50	0.14	1.51	3.17	6.57
SC x ½ RD	0.43	5.60	17.43	48.67	0.12	1.31	3.03	5.97
SC x RD	0.53	6.70	20.27	51.43	0.13	1.61	3.30	6.60
S.Ed.±	0.03	0.14	0.98	4.85	0.01	0.08	0.18	0.17
CD (at 5%)	0.07	NS	NS	NS	0.04	NS	NS	NS

Table 6 : Root, shoot yield (t ha⁻¹) and shoot-root ratio of carrot as affected by cropping system and INM practices

Treatments	Root yield	Shoot yield	Shoot-root ratio
<i>Cropping systems (Main treatments)</i>			
Under Planting (UP)	10.02	16.96	1.70
Inter Cropping (IC)	12.63	18.06	1.44
Sole Cropping (SC)	19.15	18.03	1.01
S.Ed.±	0.54	0.93	0.06
CD (at 5%)	1.49	NS	0.18
<i>INM practices (Sub treatments)</i>			
Vermicompost+½ RD NPK (VC)	14.14	17.21	1.31
Neem Cake+½ RD NPK (NC)	14.71	18.78	1.47
Castor Cake+½ RD NPK (CC)	15.86	18.73	1.25
FYM+½ RD NPK (FYM)	13.93	18.14	1.41
½ RD NPK only (½ RD)	10.10	14.19	1.47
RD NPK (RD)	14.87	19.05	1.38
S.Ed.±	0.40	0.94	0.07
CD (at 5%)	0.82	1.92	0.15
<i>Interaction (Main x Sub)</i>			
UP x VC	9.60	14.77	1.54
UP x NC	10.53	17.53	1.67
UP x CC	11.27	17.03	1.52
UP x FYM	9.87	17.70	1.79
UP x ½ RD	8.53	16.10	1.89
UP x RD	10.33	18.63	1.81
IC x VC	12.30	17.86	1.46
IC x NC	13.60	19.53	1.44
IC x CC	14.33	18.90	1.32
IC x FYM	12.63	18.90	1.49
IC x ½ RD	9.17	13.73	1.49
IC x RD	13.77	19.47	1.41
SC x VC	20.53	19.03	0.93
SC x NC	20.00	19.27	1.31
SC x CC	21.97	20.27	0.92
SC x FYM	19.30	17.83	0.93
SC x ½ RD	12.60	12.73	1.02
SC x RD	20.50	19.07	0.93
S.Ed.±	0.69	2.18	0.13
CD (at 5%)	1.41	NS	NS

Table 7 : Carotene (mg/100g), sugars (%) and TSS (°Brix) content of carrot root as affected by cropping system and INM practices

Treatments	Carotene content	Reducing sugars	Non-reducing sugars	Total sugars	TSS
<i>Cropping systems (Main treatments)</i>					
Under Planting (UP)	3.96	3.75	4.05	7.81	11.99
Inter Cropping (IC)	4.05	3.90	4.10	8.02	12.37
Sole Cropping (SC)	4.22	4.00	4.22	8.19	13.09
S.Ed.±	0.05	0.01	0.12	0.10	0.10
CD (at 5%)	0.15	0.04	NS	0.28	0.28
<i>INM practices (Sub treatments)</i>					
Vermicompost+½ RD NPK (VC)	4.09	3.88	4.10	7.99	12.50
Neem Cake+½ RD NPK (NC)	4.42	3.98	4.16	8.14	12.81
Castor Cake+½ RD NPK (CC)	4.08	3.97	4.12	8.09	12.53
FYM+½ RD NPK (FYM)	4.00	3.80	4.21	7.92	12.33
½ RD NPK only (½ RD)	3.82	3.75	4.07	7.83	12.29
RD NPK (RD)	4.05	3.95	4.08	8.05	12.42
S.Ed.±	0.08	0.08	0.19	0.16	0.14
CD (at 5%)	0.17	0.17	NS	NS	0.28
<i>Interaction (Main x Sub)</i>					
UP x VC	4.07	3.70	4.07	7.77	12.03
UP x NC	4.23	3.87	4.13	8.02	12.17
UP x CC	3.93	3.80	3.87	7.63	12.07
UP x FYM	4.03	3.70	4.23	7.97	11.90
UP x ½ RD	3.67	3.67	4.00	7.68	11.87
UP x RD	3.83	3.80	4.00	7.81	11.90
IC x VC	3.97	3.90	4.10	8.02	12.43
IC x NC	4.43	3.97	4.03	8.01	13.00
IC x CC	4.07	4.00	4.33	8.36	12.43
IC x FYM	3.97	3.83	4.03	7.87	12.10
IC x ½ RD	3.87	3.77	4.03	7.82	12.03
IC x RD	4.03	3.97	4.06	8.03	12.20
SC x VC	4.23	4.03	4.13	8.20	13.03
SC x NC	4.60	4.10	4.30	8.42	13.27
SC x CC	4.23	4.10	4.17	8.28	13.10
SC x FYM	4.00	3.87	4.37	7.93	13.00
SC x ½ RD	3.93	3.83	4.17	8.00	12.97
SC x RD	4.30	4.10	4.17	8.30	13.17
S.Ed.±	0.14	0.15	0.33	0.28	0.24
CD (at 5%)	NS	NS	NS	NS	NS

Table 8 : N, P, K (%) and total chlorophyll (mg/100g sample) of carrot shoot as affected by cropping system and INM practices

Treatments	N	P	K	Total chlorophyll
<i>Cropping systems (Main treatments)</i>				
Under Planting (UP)	1.71	0.24	2.52	1.56
Inter Cropping (IC)	1.84	0.29	2.71	1.37
Sole Cropping (SC)	1.86	0.29	2.91	1.26
S.Ed.±	0.01	0.003	0.02	0.02
CD (at 5%)	0.03	0.01	0.06	0.05
<i>INM practices (Sub treatments)</i>				
Vermicompost+½ RD NPK (VC)	1.79	0.28	2.68	1.38
Neem Cake+½ RD NPK (NC)	1.82	0.28	2.82	1.39
Castor Cake+½ RD NPK (CC)	1.86	0.30	2.89	1.40
FYM+½ RD NPK (FYM)	1.74	0.28	2.76	1.38
½ RD NPK only (½ RD)	1.66	0.24	2.25	1.39
RD NPK (RD)	1.92	0.28	2.87	1.42
S.Ed.±	0.01	0.004	0.02	0.17
CD (at 5%)	0.02	0.009	0.04	NS
<i>Interaction (Main x Sub)</i>				
UP x VC	1.74	0.24	2.50	1.50
UP x NC	1.69	0.23	2.54	1.58
UP x CC	1.68	0.27	2.67	1.59
UP x FYM	1.64	0.25	2.71	1.54
UP x ½ RD	1.59	0.22	2.09	1.54
UP x RD	1.91	0.23	2.63	1.60
IC x VC	1.86	0.29	2.59	1.36
IC x NC	1.88	0.29	2.81	1.34
IC x CC	1.97	0.30	2.92	1.37
IC x FYM	1.77	0.29	2.79	1.36
IC x ½ RD	1.70	0.27	2.27	1.38
IC x RD	1.86	0.30	2.91	1.39
SC x VC	1.78	0.31	2.96	1.30
SC x NC	1.87	0.31	3.10	1.25
SC x CC	1.94	0.31	3.09	1.26
SC x FYM	1.80	0.30	2.80	1.25
SC x ½ RD	1.69	0.23	2.39	1.24
SC x RD	1.98	0.31	3.09	1.26
S.Ed.±	0.01	0.01	0.04	0.03
CD (at 5%)	0.03	0.02	0.08	NS

Table 9 : N, P and K uptake (kg ha⁻¹) by carrot under different cropping system and INM practices

Treatments	N uptake	P uptake	K uptake
<i>Cropping systems (Main treatments)</i>			
Under Planting (UP)	17.46	2.30	22.07
Inter Cropping (IC)	29.61	4.80	42.89
Sole Cropping (SC)	36.59	6.44	62.99
S.Ed.±	0.54	0.15	0.52
CD (at 5%)	1.49	0.42	1.46
<i>INM practices (Sub treatments)</i>			
Vermicompost+½ RD NPK (VC)	28.12	4.26	42.96
Neem Cake+½ RD NPK (NC)	28.85	4.75	46.49
Castor Cake+½ RD NPK (CC)	29.95	4.99	48.49
FYM+½ RD NPK (FYM)	26.73	4.85	43.59
½ RD NPK only (½ RD)	22.69	3.38	31.72
RD NPK (RD)	30.98	4.83	46.66
S.Ed.±	0.88	0.32	1.07
CD (at 5%)	1.79	0.65	2.20
<i>Interaction (Main x Sub)</i>			
UP x VC	17.81	2.31	23.99
UP x NC	18.06	2.22	23.48
UP x CC	19.53	2.73	26.82
UP x FYM	16.08	2.53	26.84
UP x ½ RD	13.65	1.78	17.07
UP x RD	19.05	2.22	25.24
IC x VC	31.63	3.91	41.49
IC x NC	31.37	5.24	47.20
IC x CC	32.38	5.31	48.59
IC x FYM	27.59	5.43	42.73
IC x ½ RD	22.75	4.05	30.46
IC x RD	31.95	4.88	46.87
SC x VC	34.92	6.58	63.42
SC x NC	37.12	6.81	67.79
SC x CC	37.94	6.94	70.07
SC x FYM	35.92	6.61	61.21
SC x ½ RD	31.67	4.32	47.62
SC x RD	41.95	7.38	67.87
S.Ed.±	152	0.54	1.39
CD (at 5%)	NS	NS	2.94

Table 11 : Diurnal variations in mean leaf temperature and relative humidity of carrot as affected by cropping system and INM practices at grand growth period

Treatments	Leaf temperature (°C)			Relative humidity (%)		
	8.00 hrs	12.00 hrs	16.00 hrs	8.00 hrs	12.00 hrs	16.00 hrs
<i>Cropping systems (Main treatments)</i>						
Under Planting (UP)	25.32	30.35	28.10	36.20	32.75	30.93
Inter Cropping (IC)	26.30	31.09	30.33	34.03	31.53	30.13
Sole Cropping (SC)	27.09	32.50	31.45	32.06	30.52	29.00
S.Ed.±	0.44	0.31	0.59	1.05	0.18	0.26
CD (at 5%)	1.21	0.87	1.66	2.92	0.49	0.72
<i>INM practices (Sub treatments)</i>						
Vermicompost+½ RD NPK (VC)	26.77	31.23	29.87	33.44	31.07	29.67
Neem Cake+½ RD NPK (NC)	26.49	31.47	29.69	34.13	31.89	30.54
Castor Cake+½ RD NPK (CC)	26.23	31.64	29.98	34.06	31.34	29.52
FYM+½ RD NPK (FYM)	25.44	31.14	30.09	34.33	31.91	30.72
½ RD NPK only (½ RD)	25.34	31.14	29.90	34.44	31.19	29.93
RD NPK (RD)	27.15	31.25	30.27	34.15	32.21	29.73
S.Ed.±	0.65	0.44	0.39	1.01	0.28	0.78
CD (at 5%)	NS	NS	NS	NS	0.59	NS
<i>Interaction (Main x Sub)</i>						
UP x VC	26.10	30.33	28.70	34.83	32.40	31.17
UP x NC	25.50	30.27	28.03	35.67	33.10	31.27
UP x CC	25.77	30.17	27.43	35.83	32.30	30.97
UP x FYM	24.57	30.43	28.20	36.50	33.10	31.33
UP x ½ RD	24.57	30.23	27.83	37.47	32.33	30.57
UP x RD	25.43	30.67	28.43	36.90	33.30	30.27
IC x VC	26.93	31.07	30.00	34.46	31.00	28.83
IC x NC	26.73	31.53	29.73	34.30	31.17	30.10
IC x CC	25.90	31.47	31.03	35.63	31.47	28.90
IC x FYM	25.60	30.40	30.70	33.80	32.10	30.77
IC x ½ RD	25.07	30.77	30.07	32.70	31.20	31.17
IC x RD	28.10	31.33	30.47	33.27	32.27	31.03
SC x VC	27.27	32.30	30.90	31.03	29.83	29.00
SC x NC	27.73	32.60	31.30	32.43	31.40	30.27
SC x CC	27.03	33.30	31.47	30.73	30.27	28.70
SC x FYM	26.17	32.60	31.37	32.70	30.53	30.07
SC x ½ RD	26.40	32.43	31.80	33.17	30.03	28.07
SC x RD	27.93	31.77	31.90	32.30	31.07	27.90
S.Ed.±	1.13	0.76	1.36	2.46	0.49	1.34
CD (at 5%)	NS	NS	NS	NS	NS	NS

Table 12 : Diurnal variations in diffusive resistance and transpiration rate of carrot as affected by cropping system and INM practices at grand growth period

Treatments	Diffusive resistance (s cm ⁻¹)			Transpiration rate (μg cm ⁻² s ⁻¹)		
	8.00 hrs	12.00 hrs	16.00 hrs	8.00 hrs	12.00 hrs	16.00 hrs
<i>Cropping systems (Main treatments)</i>						
Under Planting (UP)	0.37	0.44	0.38	13.33	12.38	11.58
Inter Cropping (IC)	0.33	0.37	0.35	14.22	13.35	12.57
Sole Cropping (SC)	0.28	0.33	0.27	16.24	15.37	14.44
S.Ed.±	0.01	0.01	0.01	0.04	0.10	0.04
CD (at 5%)	0.04	0.02	0.02	0.12	0.29	0.11
<i>INM practices (Sub treatments)</i>						
Vermicompost+½ RD NPK (VC)	0.34	0.37	0.33	14.50	13.48	12.74
Neem Cake+½ RD NPK (NC)	0.35	0.41	0.34	14.60	13.68	12.93
Castor Cake+½ RD NPK (CC)	0.33	0.39	0.33	14.53	13.74	12.89
FYM+½ RD NPK (FYM)	0.32	0.39	0.33	14.53	13.69	12.87
½ RD NPK only (½ RD)	0.28	0.37	0.32	14.69	13.79	12.83
RD NPK (RD)	0.33	0.36	0.33	14.75	13.84	12.91
S.Ed.±	0.02	0.01	0.01	0.07	0.18	0.08
CD (at 5%)	NS	0.03	NS	0.15	NS	NS
<i>Interaction (Main x Sub)</i>						
UP x VC	0.37	0.43	0.39	13.40	12.20	11.60
UP x NC	0.39	0.50	0.38	13.50	12.33	11.70
UP x CC	0.38	0.48	0.38	13.20	12.27	11.57
UP x FYM	0.37	0.43	0.37	13.07	12.17	11.47
UP x ½ RD	0.36	0.41	0.37	13.30	12.53	11.50
UP x RD	0.38	0.41	0.39	13.50	12.80	11.63
IC x VC	0.35	0.36	0.34	14.10	13.17	12.43
IC x NC	0.38	0.40	0.37	14.20	13.30	12.57
IC x CC	0.34	0.37	0.35	14.40	13.60	12.70
IC x FYM	0.34	0.37	0.36	14.10	13.40	12.67
IC x ½ RD	0.22	0.35	0.34	14.23	13.23	12.40
IC x RD	0.34	0.37	0.35	14.33	13.43	12.63
SC x VC	0.30	0.31	0.27	16.00	15.07	14.20
SC x NC	0.29	0.33	0.28	16.10	15.40	14.53
SC x CC	0.27	0.33	0.27	16.00	15.37	14.40
SC x FYM	0.28	0.37	0.27	16.43	15.50	14.47
SC x ½ RD	0.27	0.34	0.26	16.53	15.60	14.60
SC x RD	0.26	0.32	0.26	16.40	15.30	14.47
S.Ed.±	0.04	0.02	0.02	0.13	0.31	0.14
CD (at 5%)	NS	NS	NS	0.26	NS	NS

Table 10 : Diurnal variations in quantum (PAR) and per cent reduction in PAR over sole of carrot as affected by cropping system and INM practices at grand growth period

Treatments	Quantum ($\mu \text{ mol s}^{-1} \text{ m}^{-2}$)			Per cent available PAR compared to sole (%)		
	8.00 hrs	12.00 hrs	16.00 hrs	8.00 hrs	12.00 hrs	16.00 hrs
<i>Cropping systems (Main treatments)</i>						
Under Planting (UP)	469.39	343.17	378.50	43.10	28.69	35.70
Inter Cropping (IC)	767.44	711.78	763.44	70.47	59.50	72.00
Sole Cropping (SC)	1089.00	1196.17	1060.28	100.00	100.00	100.00
S.Ed. $\pm$	11.10	9.42	9.78	-	-	-
CD (at 5%)	30.82	26.17	27.15	-	-	-
<i>INM practices (Sub treatments)</i>						
Vermin Compost+ $\frac{1}{2}$ RD NPK (VC)	774.89	751.11	732.78	71.16	62.79	69.11
Neem Cake+ $\frac{1}{2}$ RD NPK (NC)	773.67	748.44	735.78	71.04	62.57	69.39
Castor Cake+ $\frac{1}{2}$ RD NPK (CC)	776.67	753.11	741.89	71.32	62.96	69.97
FYM+ $\frac{1}{2}$ RD NPK (FYM)	773.44	751.55	727.78	71.02	62.83	68.64
$\frac{1}{2}$ RD NPK only ($\frac{1}{2}$ RD)	776.44	748.44	732.55	71.30	62.57	69.09
RD NPK (RD)	776.55	749.55	733.67	71.31	62.66	69.19
S.Ed. $\pm$	8.60	16.18	11.13	-	-	-
CD (at 5%)	NS	NS	NS	-	-	-
<i>Interactions (Main x Sub)</i>						
UP x VC	468.00	343.33	380.00	42.97	28.70	35.84
UP x NC	469.33	340.00	377.33	43.09	28.42	35.59
UP x CC	470.00	345.00	380.00	43.16	28.84	35.84
UP x FYM	469.00	344.33	376.67	43.07	28.79	35.52
UP x $\frac{1}{2}$ RD	472.00	344.00	378.33	43.34	28.76	35.68
UP x RD	468.00	342.33	378.67	42.97	28.62	35.71
IC x VC	766.67	713.33	761.67	70.40	59.63	71.84
IC x NC	766.67	712.00	756.67	70.40	59.52	71.36
IC x CC	768.33	711.00	777.33	70.55	59.44	73.31
IC x FYM	767.33	713.67	756.67	70.46	59.66	71.36
IC x $\frac{1}{2}$ RD	767.33	709.67	762.67	70.46	59.33	71.93
IC x RD	768.33	711.00	765.67	70.55	59.44	72.21
SC x VC	1090.00	1196.67	1056.67	-	-	-
SC x NC	1085.00	1193.33	1073.33	-	-	-
SC x CC	1091.67	1203.33	1068.33	-	-	-
SC x FYM	1084.00	1196.67	1050.00	-	-	-
SC x $\frac{1}{2}$ RD	1090.00	1191.67	1056.67	-	-	-
SC x RD	1093.33	1195.33	1056.67	-	-	-
S.Ed. $\pm$	24.05	28.03	23.25	-	-	-
CD (at 5%)	NS	NS	NS	-	-	-

Table 13 : Fruit yield and average fruit weight of ber fruit as affected by cropping system and INM practices

Treatments	Fruit yield (kg plant⁻¹)	Fruit yield (t ha⁻¹)	Average fruit weight (g)
Ber UP Carrot VC	36.40	5.60	21.40
Ber UP Carrot NC	38.30	5.93	21.63
Ber UP Carrot CC	34.60	5.33	20.90
Ber UP Carrot FYM	32.83	5.07	20.33
Ber UP Carrot 50% RD	30.53	4.73	19.73
Ber UP Carrot 100% RD	35.40	5.50	20.00
Ber IC Carrot VC	32.36	5.03	19.87
Ber IC Carrot NC	31.23	4.83	20.33
Ber IC Carrot CC	32.00	4.97	20.33
Ber IC Carrot FYM	29.57	4.63	19.67
Ber IC Carrot 50% RD	29.00	4.53	19.47
Ber IC Carrot 100% RD	30.17	4.63	19.80
Sole ber	30.03	4.60	20.23
S.Ed.±	1.63	0.26	1.05
CD (at 5%)	3.36	0.53	NS

Table 14 : Sugars, TSS and acidity content of ber fruit as affected by cropping system and INM practices

Treatments	Reducing sugars (%)	Non-reducing sugars (%)	TSS (°Brix)	Acidity (%)
Ber UP Carrot VC	3.17	4.60	14.93	0.29
Ber UP Carrot NC	3.23	5.00	14.90	0.30
Ber UP Carrot CC	3.10	4.50	15.03	0.29
Ber UP Carrot FYM	3.07	4.83	14.77	0.31
Ber UP Carrot 50% RD	3.00	4.80	14.77	0.30
Ber UP Carrot 100% RD	3.20	4.83	15.07	0.29
Ber IC Carrot VC	3.10	4.57	14.63	0.28
Ber IC Carrot NC	3.17	4.93	14.77	0.30
Ber IC Carrot CC	2.93	4.60	14.93	0.29
Ber IC Carrot FYM	3.00	4.77	14.73	0.30
Ber IC Carrot 50% RD	2.87	4.80	14.57	0.32
Ber IC Carrot 100% RD	3.17	4.93	14.57	0.29
Sole ber	3.00	4.90	14.97	0.29
S.Ed.±	0.11	0.19	0.28	2.41
CD (at 5%)	NS	NS	NS	NS

Table 15 : N, P and K content (%) of ber leaves as affected by cropping system and INM practices

Treatments	Nitrogen	Phosphorus	Potassium
Ber UP Carrot VC	2.02	0.13	1.17
Ber UP Carrot NC	2.03	0.15	1.18
Ber UP Carrot CC	2.04	0.16	1.18
Ber UP Carrot FYM	1.99	0.12	1.14
Ber UP Carrot 50% RD	2.01	0.12	1.13
Ber UP Carrot 100% RD	2.03	0.14	1.18
Ber IC Carrot VC	2.00	0.12	1.16
Ber IC Carrot NC	2.01	0.15	1.16
Ber IC Carrot CC	2.02	0.16	1.17
Ber IC Carrot FYM	2.01	0.11	1.14
Ber IC Carrot 50% RD	2.02	0.11	1.12
Ber IC Carrot 100% RD	2.02	0.14	1.16
Sole ber	2.00	0.12	1.14
S.Ed.±	3.53	1.72	1.41
CD (at 5%)	NS	NS	NS

Table 16 : Gross and net income (Rs. ha⁻¹) under different treatments as affected by cropping system and INM practices

Treatments	Gross income			Total net income
	Ber	Carrot	Total	
UP x VC + 50% RD NPK	28000	28800	56800	10718
UP x NC + 50% RD NPK	29667	31600	61266	19585
UP x CC + 50% RD NPK	26667	33800	60467	19585
UP x FYM + 50% RD NPK	25333	29600	54933	23201
UP x 50% RD NPK only	23667	25600	49267	21185
UP x 100% RD NPK only	27500	31000	58500	28852
IC x VC + 50% RD NPK	25167	36900	62067	15985
IC x NC + 50% RD NPK	24167	40800	64967	23285
IC x CC + 50% RD NPK	24833	43000	67833	26951
IC x FYM + 50% RD NPK	23167	37900	61067	29335
IC x 50% RD NPK only	22667	27533	50167	22085
IC x 100% RD NPK only	23167	41300	64467	34819
SC x VC + 50% RD NPK	-	61600	61600	29172
SC x NC + 50% RD NPK	-	60000	60000	31972
SC x CC + 50% RD NPK	-	65900	65900	38672
SC x FYM + 50% RD NPK	-	57900	57900	33796
SC x 50% RD NPK only	-	37800	37800	23372
SC x 100% RD NPK only	-	61500	61500	45506
Sole ber	23000	-	23000	9346
S.Ed.±			2519	3122
CD (at 5%)			5134	6363

Table 17 : B:C ratio and IER under different treatments as affected by cropping system and INM practices

Treatments	B:C ratio	IER
UP x VC + 50% RD NPK	1.23	1.69
UP x NC + 50% RD NPK	1.47	1.82
UP x CC + 50% RD NPK	1.48	1.67
UP x FYM + 50% RD NPK	1.73	1.66
UP x 50% RD NPK only	1.75	1.71
UP x 100% RD NPK only	1.97	1.70
IC x VC + 50% RD NPK	1.35	1.69
IC x NC + 50% RD NPK	1.58	1.73
IC x CC + 50% RD NPK	1.66	1.73
IC x FYM + 50% RD NPK	1.92	1.66
IC x 50% RD NPK only	1.79	1.72
IC x 100% RD NPK only	2.17	1.68
SC x VC + 50% RD NPK	1.90	-
SC x NC + 50% RD NPK	2.14	-
SC x CC + 50% RD NPK	2.42	-
SC x FYM + 50% RD NPK	2.40	-
SC x 50% RD NPK only	2.62	-
SC x 100% RD NPK only	3.84	-
Sole ber	1.68	-

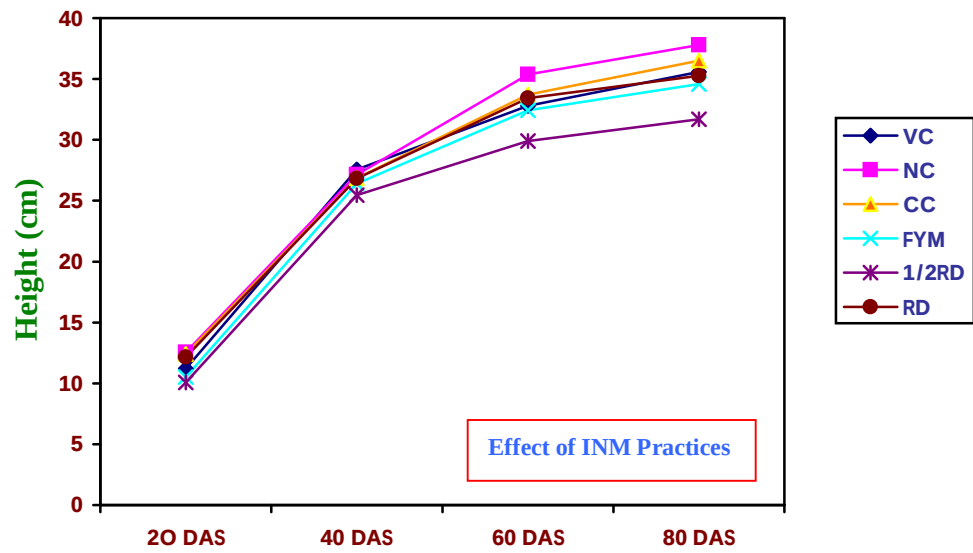
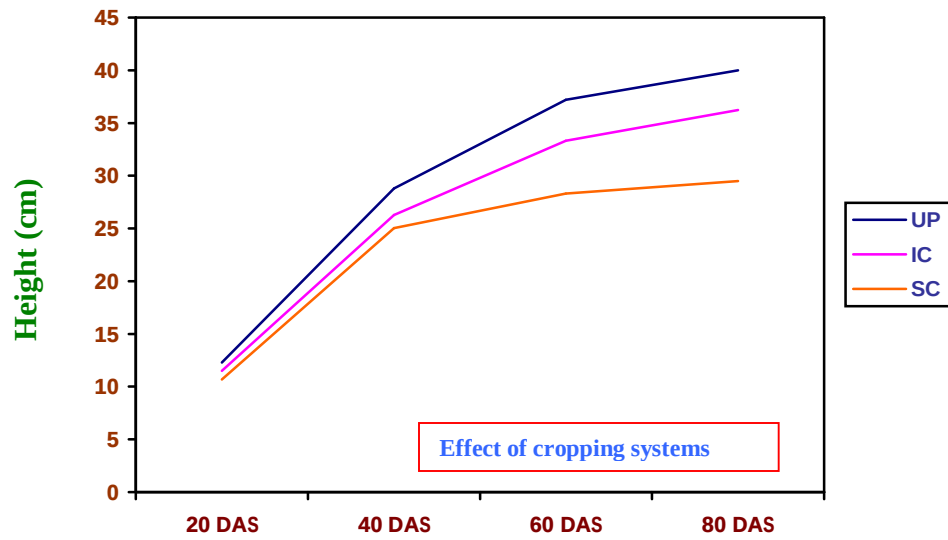
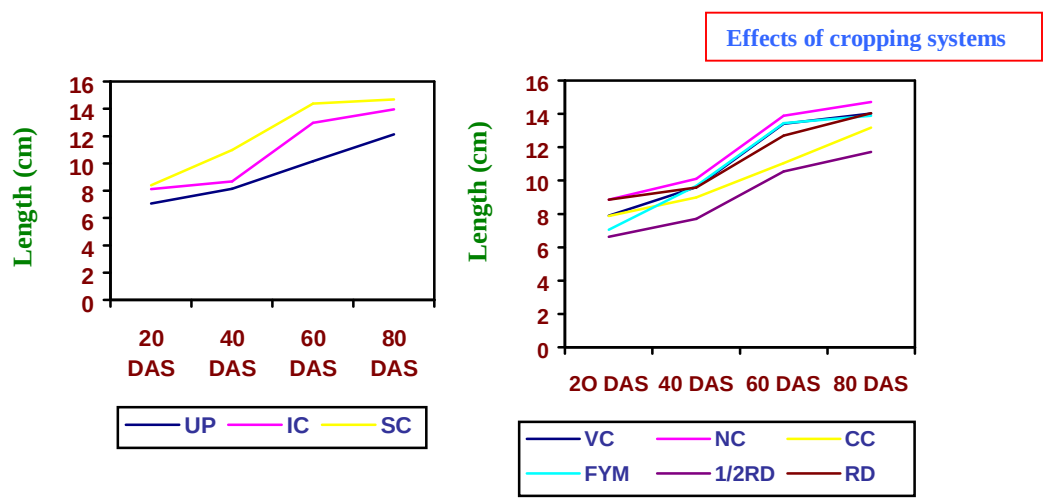


Fig.3: Plant height of carrot as affected by cropping systems and INM Practices at different stages of crop growth.

ROOT LENGTH



ROOT GIRTH

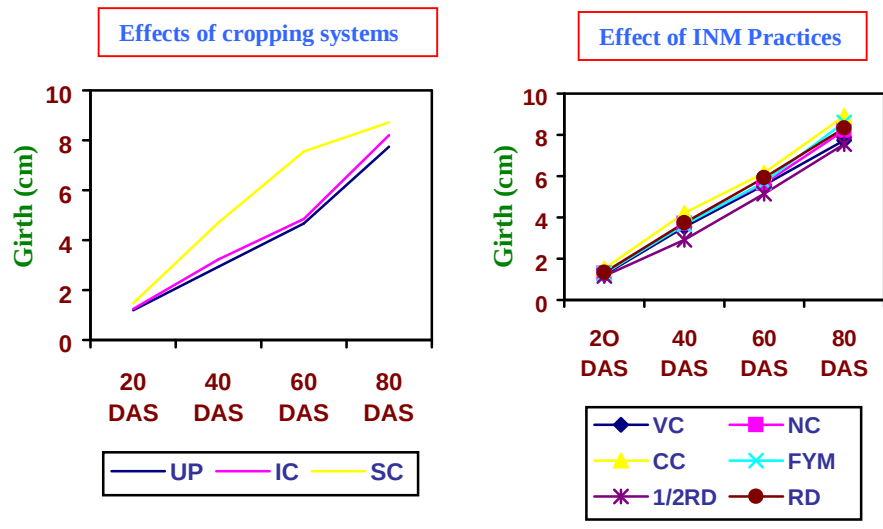


Fig.4: Root length and girth of carrot as affected by different cropping systems and INM practices at different stages of crop growth

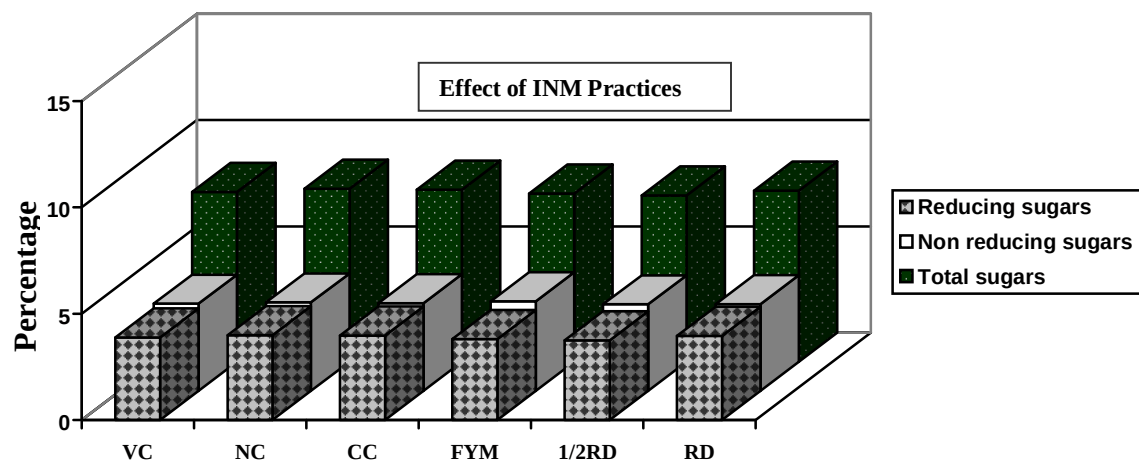
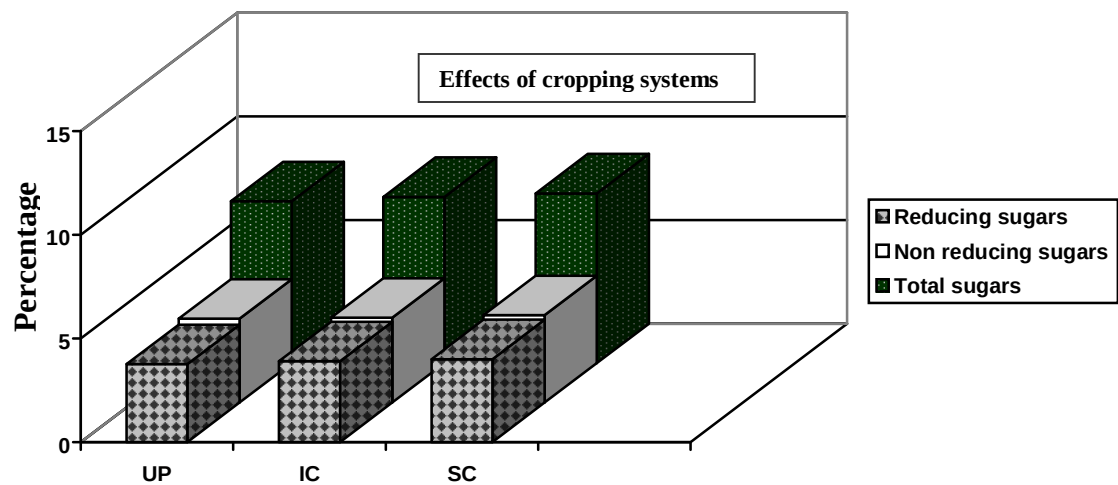


Fig.9: Reducing, non-reducing and total sugars content of carrot as affected by cropping systems and INM practices.

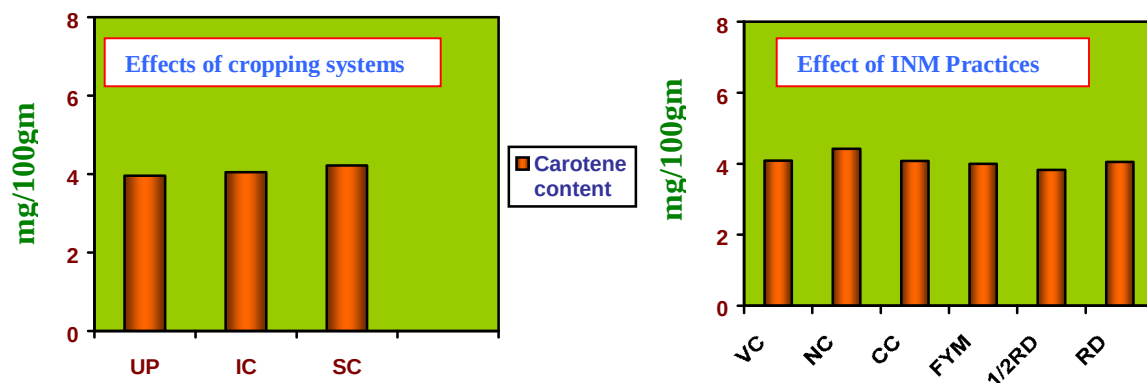


Fig 7: Carotene content of carrot as affected by different cropping systems and INM practices

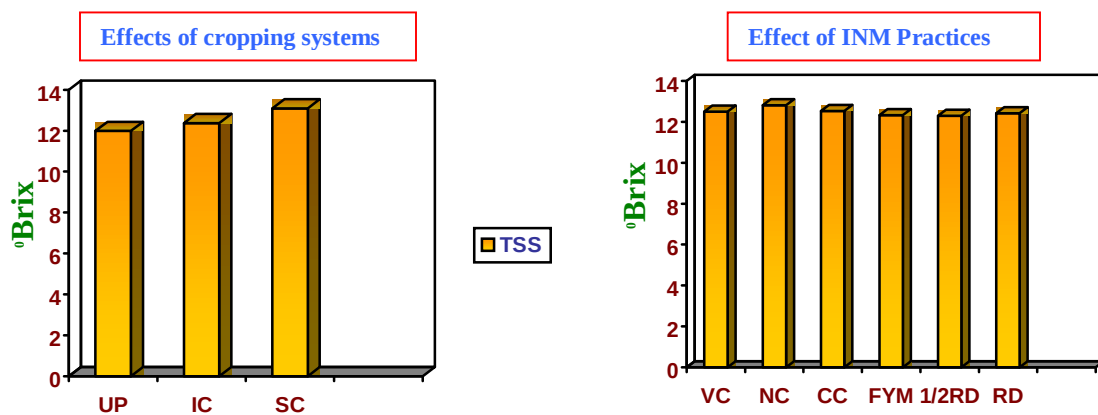


Fig. 8: TSS content of carrot as affected by cropping systems and INM practices

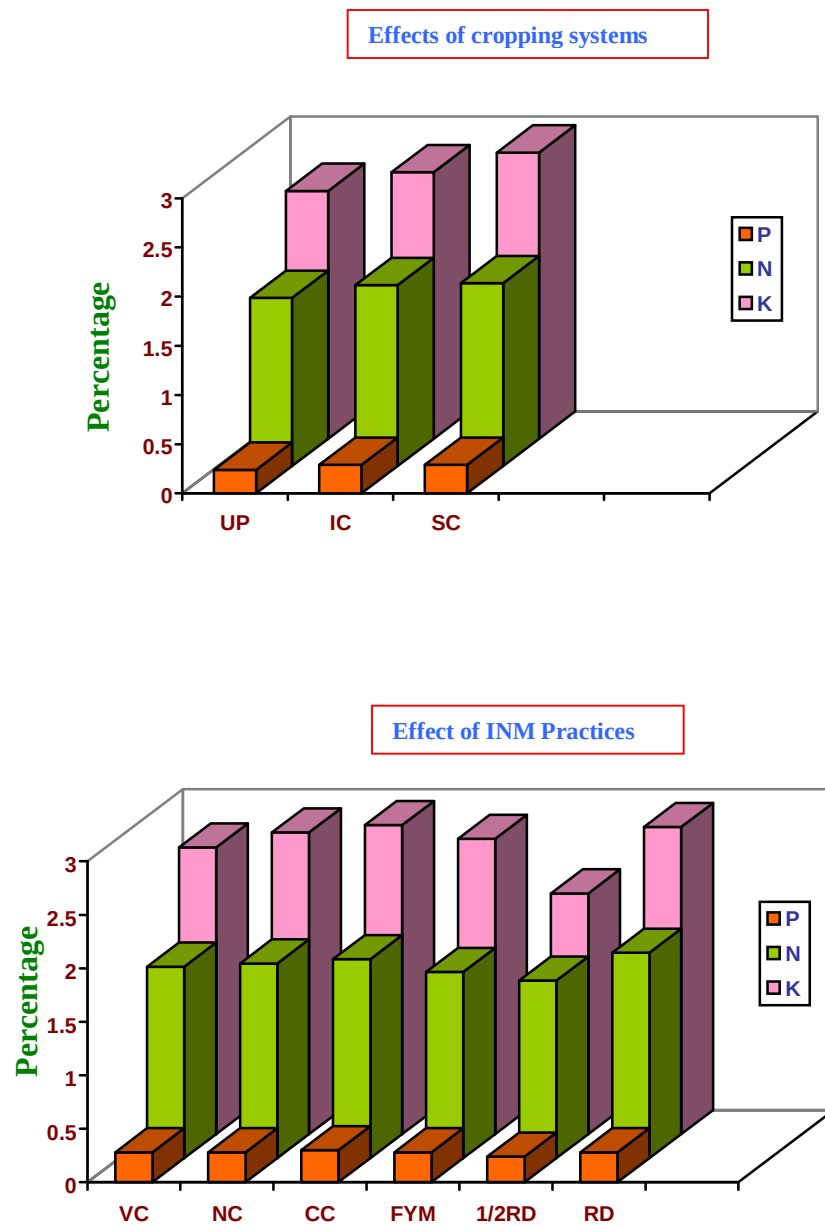


Fig.10: N, P and K content of carrot as affected by cropping systems and INM practices.

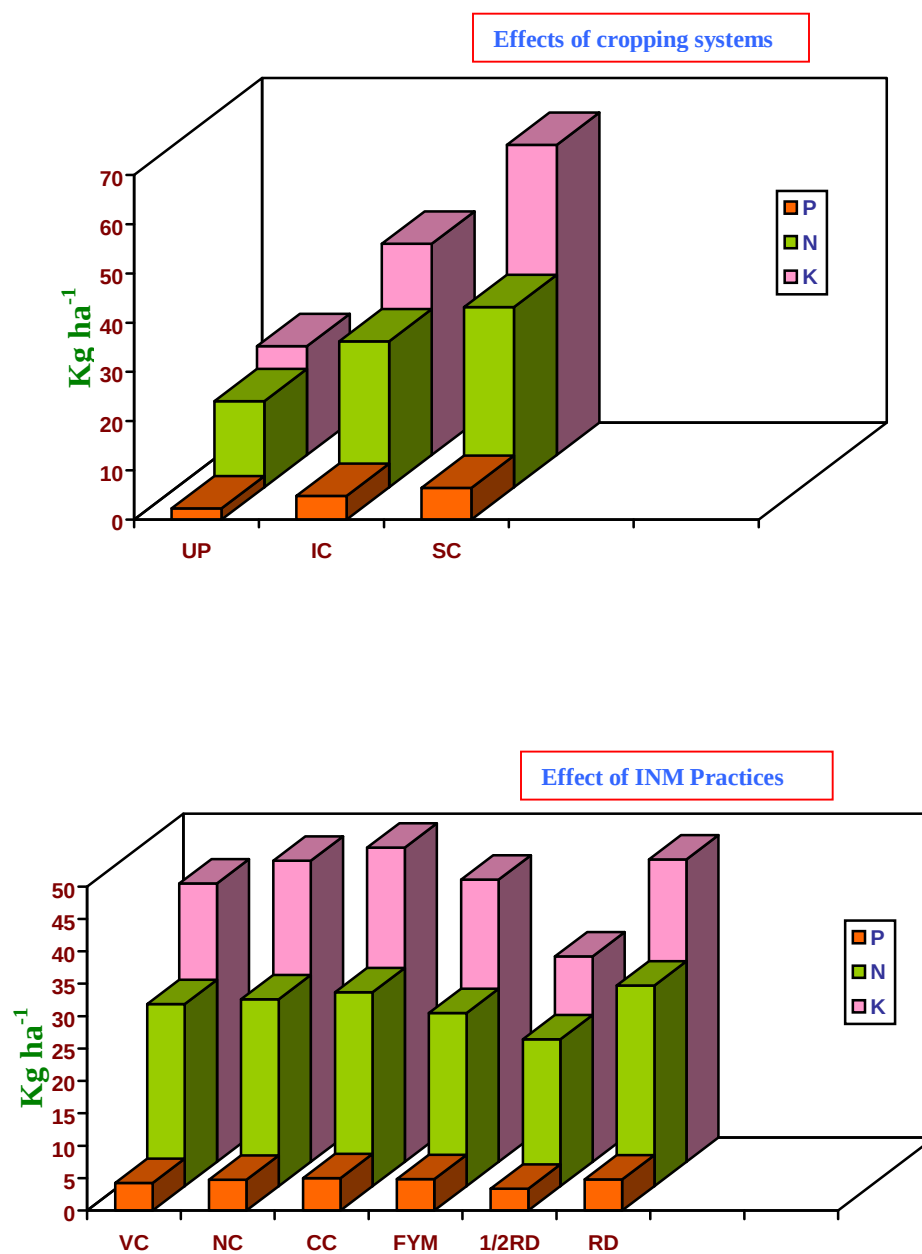


Fig.11: N, P and K uptake by carrot under different cropping systems and INM practices.

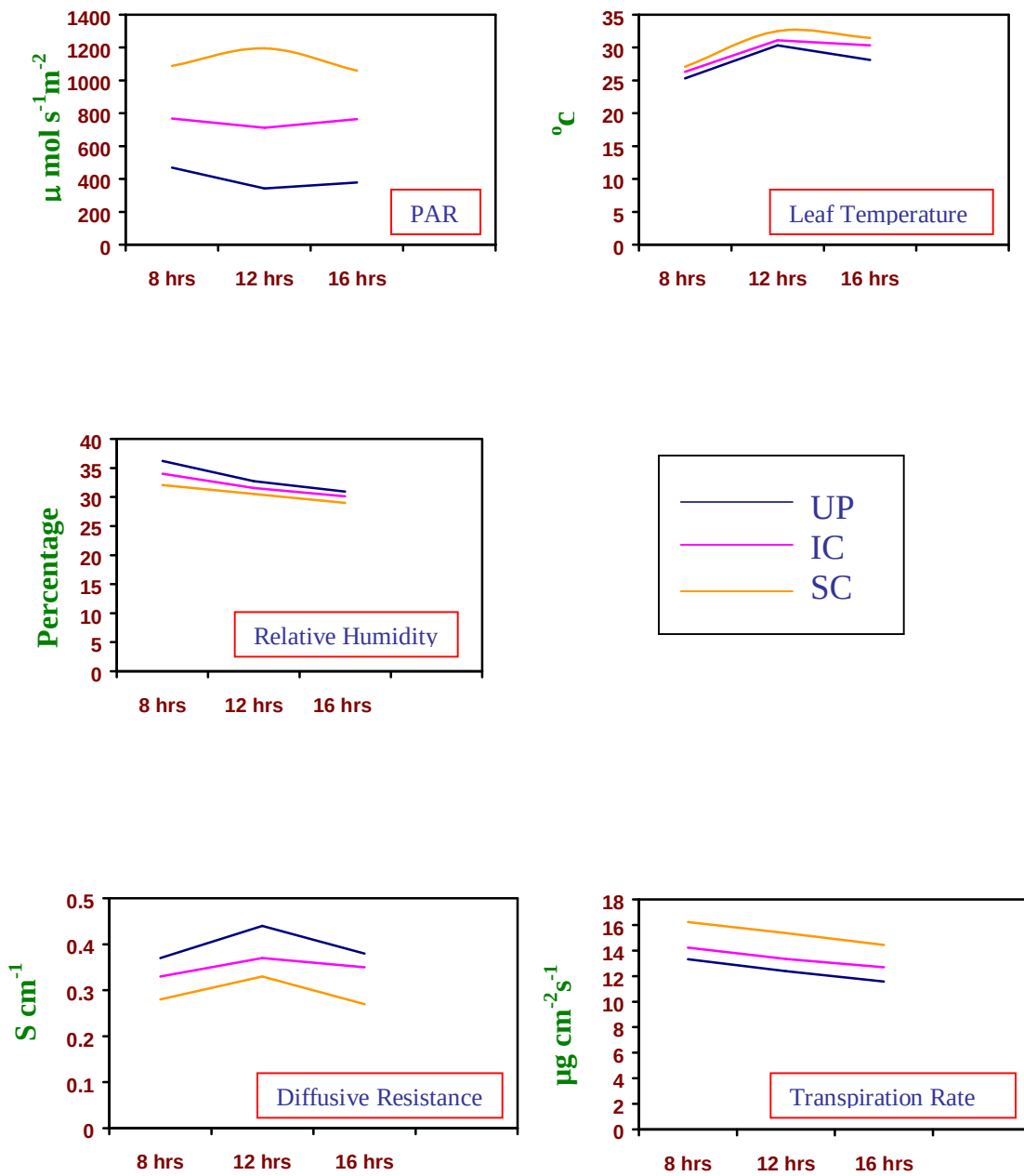


Fig.12: Diurnal variations in microclimatic and physiological parameters of carrot as affected by different cropping systems.

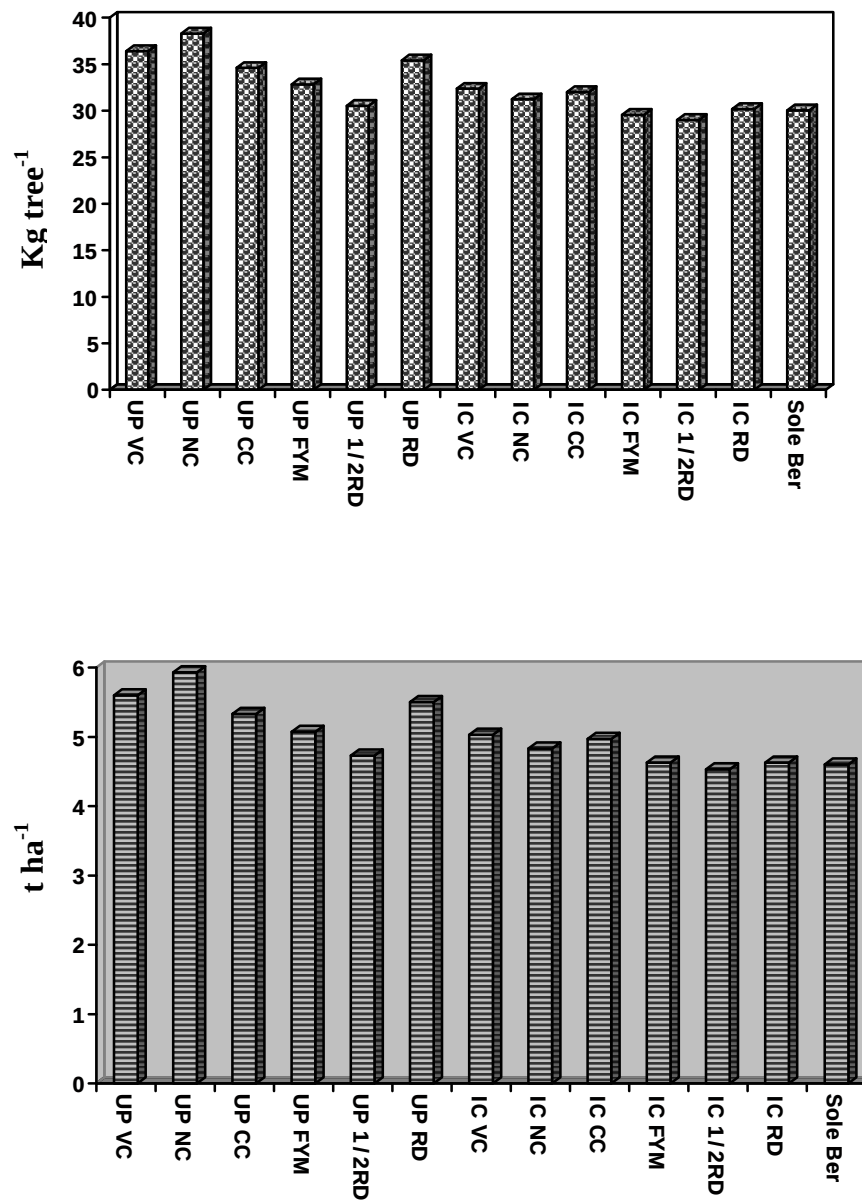
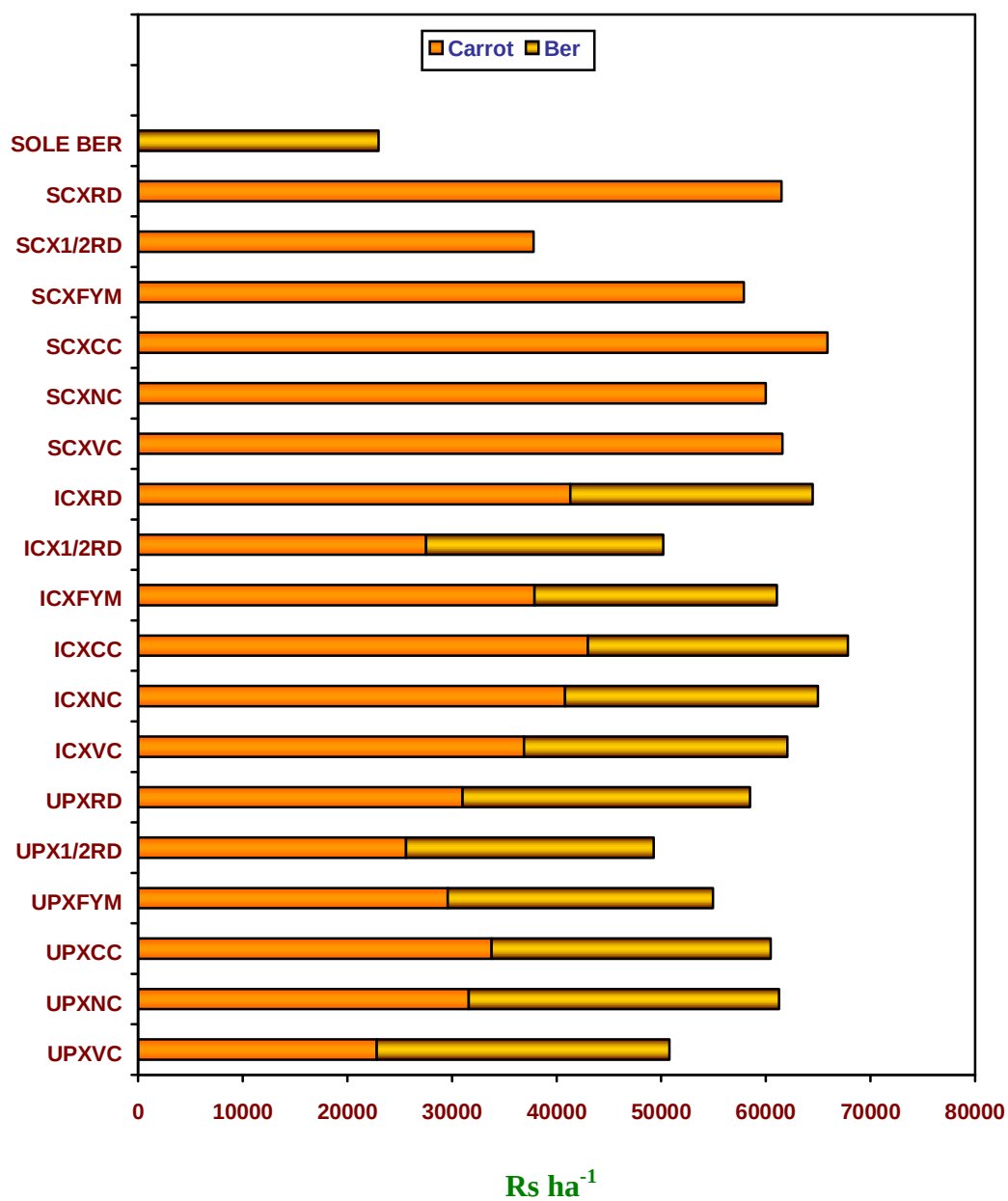
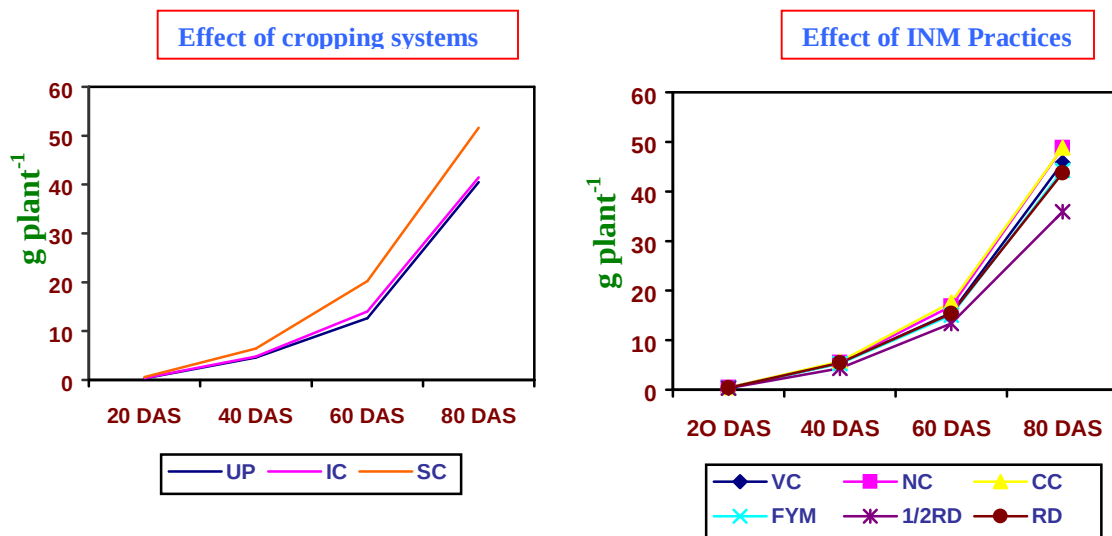


Fig13: Fruit yield of Ber (kg tree^{-1} / tonnes ha^{-1}) as affected by different INM practices of carrot under different cropping systems

Fig.14: Component wise mean gross returns from different treatments in different cropping systems and INM practices



FRESH WEIGHT



DRY WEIGHT

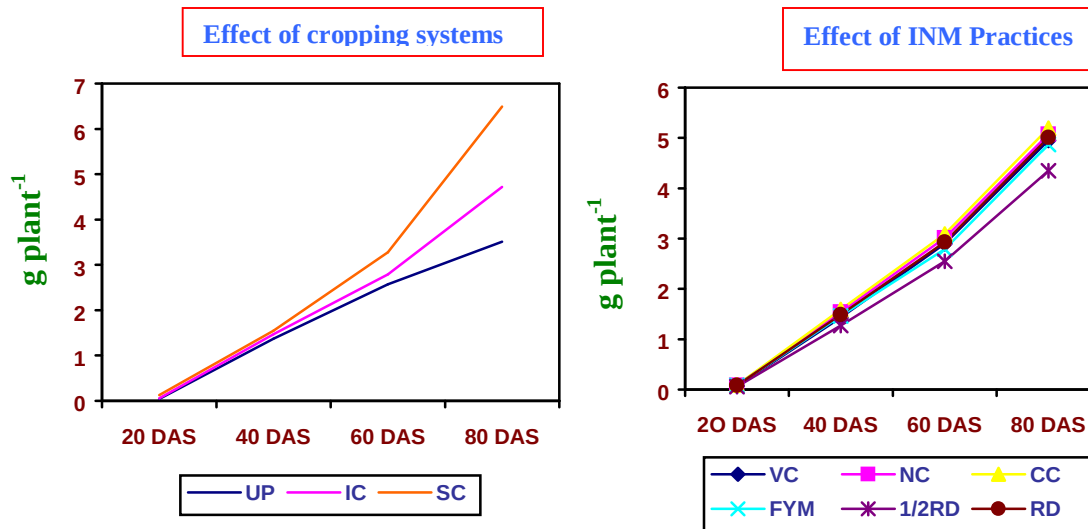


Fig.5: Fresh and dry weight of carrot root as affected by cropping systems and INM practices at different stages of crop growth

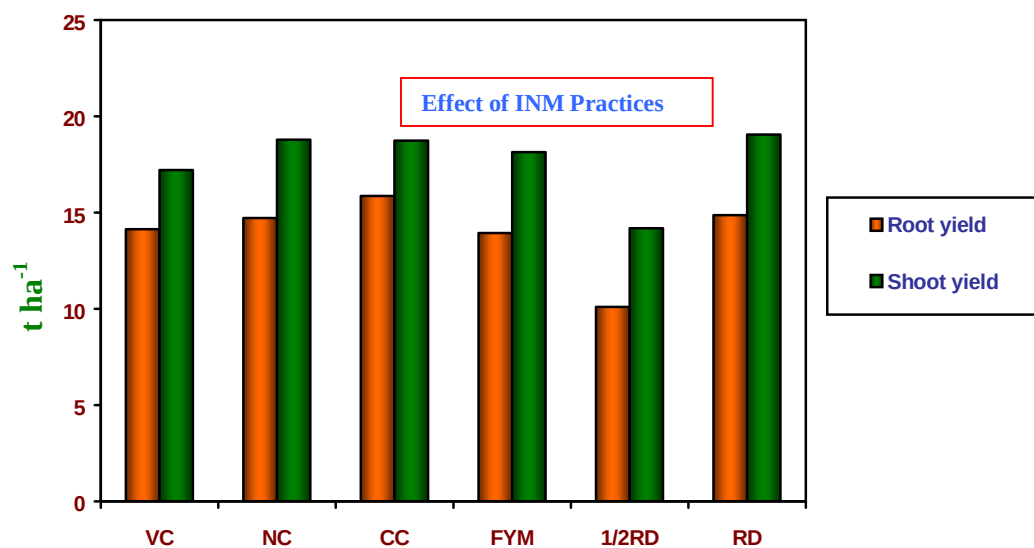
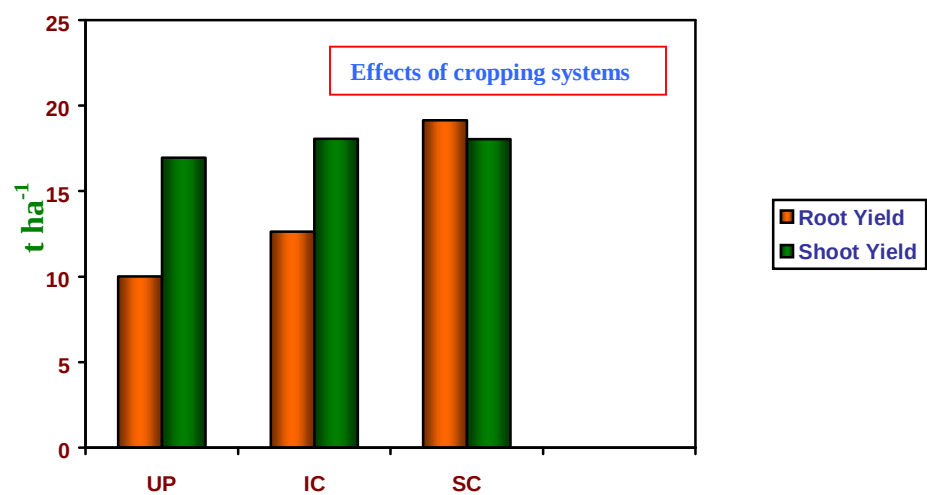


Fig.6: Root and shoot yield of carrot as affected by cropping system and INM practices.

CHAPTER – V

DISCUSSION

Performance of carrot under different cropping situations and INM practices in respect of plant growth, yield, quality, changes in microclimatic and physiological parameters and productivity and also the effect of INM practices of carrot on yield, quality and productivity of ber are discussed in this chapter.

5.1 Effect of cropping systems on growth, yield and quality of carrot

There was significant increase in plant height of carrot at all stages of plant growth when underplanted in ber followed by intercropping and least in sole crop. The increased plant height of carrot in under planting and intercropping may be attributed to be lanky herbaceous and succulent growth under low light intensity. This may be due to the ability of the plant to reorient its leaves as high as possible for the available light. The increase in plant height of carrot in under planting and intercropping is in proportion to the reduction in available PAR under these situations compared to sole crop (Plate 2 & 3). These results may also be explained in light of the findings of Kamaruddin (1983) with tomato crop wherein he attributed the increase in plant height under shaded condition to the production of elongated internodes due to the synthesis of gibberellins and less photo oxidation of auxins causing cell elongation.

The root growth of carrot was adversely affected under shaded conditions. There was a significant reduction in root length, girth, fresh and dry weight of carrot roots when under planted in ber followed by the inter crop compared to sole crop. This may be attributed to reduction in available PAR to the extent of 57 and 30 per cent in underplanting and inter cropping situations respectively compared to sole crop which might have hampered the assimilation and transpiration of photosynthates to the roots. Sreenivasulu (2002) also reported significant reduction in root length, girth, fresh and dry weight when carrot was intercropped to the strips away from guava trees and also sole crop. Similar results were observed by Reddy *et al.* (2000) with radish when intercropped in ber.

There was a significant reduction in root yield of carrot in underplanted crop to the tune of 48 per cent followed by intercrop (34%) compared to sole crop. The reduction in yield of carrot roots in underplanted crop is not only the result of reduced availability of PAR on the crop canopy but also due to reduction in net cropped area to the extent of 10 per cent that was occupied by tree base. Pushpa Kumari and Sasidhar (1992) also reported a significant reduction in tuber yield of greater yam, lesser yam and elephant foot yam when grown under varied degree of shade. At intense shade (75), there was a severe reduction in yield and upto 25 per cent shade, there was not much yield reduction for lesser yam and elephant foot yam. The results reported by Reddy *et al.* (2000) also indicated a reduction in root yield and drymatter production of radish when intercropped with ber to the extent of 25 and 9 per

cent in the intercrop strip closer to ber and the one away from ber respectively. Similar results were also made by Sreenivasulu (2002) when carrot was intercropped with guava. These results lend support to the present findings of the performance of carrot under different cropping situations.

5.2 Effect of INM practices on growth, yield and quality of carrot

Plant height of carrot increased significantly at all stages of crop growth with the application of organic manures as compared to inorganic form of fertilizers. Among different organic manures, neem cake followed by castor cake in combination with half the recommended dose of NPK fertilizers improved the plant height at 20, 60 and 80 DAS over other treatments, while vermicompost in combination with of the recommended dose of NPK showed better effect at 40 DAS. The increase in plant height due to application of vermicompost may be attributed to its rich content of macro and micronutrients, vitamins, growth hormones and micro flora (Bhavalkar, 1991). Increased plant height with the application of neem cake with half recommended dose of NPK and castor cake with half recommended dose of NPK may be the result of higher N content (5.22 and 4.37 % respectively) in these manures. Lower plant height with FYM with half recommended dose of NPK may be attributed to its low N content (0.75%) compared to the full recommended dose of nitrogen. Nitrogen being a major element has a profound effect on plant growth and development and as a constituent of proteins and also its effect on production of plant hormones in plants. Maurya and Goswamy (1985) also found significant increase in plant height of carrot

with the application of higher doses of N than its lower dose. Amarendra Kumar *et al.* (1997) also reported significantly higher plant height with the application of neem cake in tomato, while Ravindrababu (1999) found increased plant height with the increasing levels of the vermicompost from 0 to 15 t ha⁻¹. Increase in plant height of carrot with the application of castor cake over control was also reported by Praveen Kumar (2000).

The root length of carrot was higher with organic manures and also with the full recommended dose of NPK. Among the different organic manures neem cake with half recommended dose of NPK improved root length at all the stages of plant growth compared to other treatments, but root girth, fresh and dry weight of carrot root was significantly higher with castor cake with half the recommended dose of NPK (Plate 4). This may be due to the higher content of P (1.85%) in castor cake (Appendix 2). Phosphorus stimulates root growth through greater absorption and translocation of nutrients. It is also a part of various enzymes, co-enzymes and energy rich ATP resulting in increased root growth (Mangal, 1985). Phosphorus also brings about improvement in the physico-chemical characteristics of soil (Schmidt, 1954). Increase in root girth, fresh and dry weight of root with the application of castor cake with half the recommended dose of NPK is attributed to the availability of more phosphorus and its slow release in this treatment coinciding up to the stage of root development marked with increase in girth after cessation of root length.

Oil cakes, in general, increase available phosphorus content of soil due to mineralization of organic phosphorus compounds in soil. Production of organic acids during the course of degradation of different types might play a leading role in this regard (Pareek and Gour., 1973). Full recommended dose of NPK also resulted in increased root length, girth, fresh and dry weight of carrot root. Accelerated synthesis of chlorophyll and aminoacids synthesis of chlorophyll and aminoacids and increased bio-chemical activity resulting in more translocation of photosynthates from leaves to roots might result in increase root length and girth. Similar results were also reported by Patil and Gill, (1981) in carrot who observed that nitrogen and phosphorus application significantly increased the height and fresh weight of tops, fresh and drymatter of roots, while potash increased fresh weight of tops and drymatter of roots only.

The root yield of carrot was also significantly higher with organic manures compared to inorganic fertilizers particularly with castor cake. This may be the positive effect of all yield components viz., root girth, fresh and dry weight of root in this treatment. Sandhya Rani (1998) also reported that application of higher dose of castor cake (6 t ha^{-1}) gave higher yield and uptake of nutrients in radish. Similarly increased fresh weight of root in turn the overall root yield of carrot with castor cake was reported by Praveen Kumar (2000). The full recommended dose of NPK was the next best treatment in respect of carrot yield, in which increased and readily available nutrients and their uptake might have resulted in faster synthesis. And

translocation of photosynthates from source (leaves) to sink (root). This might have contributed to increased root length and girth resulting in increased root yield. These findings are in conformity to the observation made by Devlin (1973).

Application of recommended dose of bio-fertilizers (Azatobacter and Phosphobacterium) as seed treatment to the carrot crop under different treatments to the carrot crop under different treatments involving organic manures and inorganic fertilizers might have helped in enhancing the availability of nutrients to the carrot crop. An increase in tuber yield of potato to the extent of 30 to 50 per cent with the inoculation of phosphobacterium was reported by Tilak (1991). The use of 45 kg N ha⁻¹ in combination with azatobacter increased the productivity of carrot by 50 per cent over the recommended dose of 60 kg N ha⁻¹ (Wange, 1996). In the present investigation application of azatobacter and phosphobacterium with the organic manure in combination of half the recommended dose of NPK only was on par with recommended dose of NPK and in some cases better than the recommended dose of NPK treatment. This may be due to slow release of nutrients from organic manures and their better utilization by carrot throughout the growing period which might have resulted in higher root yields of carrot. Similar findings with the application of azatobacter and phosphobacterium were observed by Kamla Singh (2000) in the tuber yields of potato.

Improvement in quality of carrot with organic manures over inorganic fertilizers was observed. Higher carotene content was recorded with neem cake (4.22 mg/100g) followed by vermicompost (4.09 mg/100g). Kolodziej and Kostecka (1994) also observed better root quality when carrot was grown with vermicompost than mineral fertilizers. Increase in carotene content with the increasing dosage of vermicompost was also reported by Ravindrababu (1999). Higher TSS content in carrot roots was recorded with neem cake (12.81° Brix) and castor cake (12.53° Brix). This may be because of better availability and uptake of nitrogen and other nutrients with the application of these manures which might have lead to balanced C/N ratio and increased activity of plant metabolism. Similar findings were made by Singh *et al.* (1970), Matura (1961), Emura and Hosoya (1979) in carrot. In radish roots also, Indumati (2000) reported an increase in TSS content with the application of vermicompost besides other organic manures and with recommended dose of fertilizers.

5.3 Influence of cropping systems on microclimatic and physiological parameters of carrot

There was a considerable reduction in per cent PAR availability on the top of carrot crop canopy to the extent of 57 per cent in underplanted crop and 30 per cent in intercropped carrot compared to sole crop at 8.00 hrs. The reduction was much drastic at 12.00 hrs to the tune of 71 per cent in underdeveloped and 40 per cent in intercropped carrot. The trend in PAR availability at 16.00 hrs was similar to that of 8.00 hrs. The drastic reduction

in PAR at 12.00 hrs in underplanted crop may be attributed to the overhead position of the sun during which time maximum radiation was intercepted by the tree canopy itself permitting very little transmission to reach to the canopy of the understoried crop. Newman (1986) also reported that the overall transitivity of the pear canopy was 73 per cent and 47 per cent reduction in PAR gave a yield reduction of 65 per cent in radish when intercropped with pear. Pushpa Kumari and Sasidhar (1992) observed a severe reduction in yield at intense shade (75%) for different root crops and recommended cultivation of greater yam upto 50 per cent shade with 30 per cent reduction in yield, while lesser and elephant foot yam can be grown under only upto 25 per cent shade without much yield reduction. Embeiri and Nwifo (1994) suggested that crops whose harvestable parts are vegetative tend to be less affected when grown in proximity to trees provided water is not limited. In the present investigations also the yield of carrot was not adversely affected even though there was considerable reduction in PAR particularly in the underplanted crop at 12.00 hrs. Since maximum photosynthetic activity takes place during morning hours, the reduction in PAR at that time was not considerably affected in underplanted carrot compared to 12.00 hrs and as such the reduction in yield of carrot was to the extent of 48 per cent as against 34 per cent in intercrop when compared to sole crop.

Underplanted carrot in ber recorded low leaf temperatures followed by intercropped carrot when compared to sole crop at all times. This may be attributed to the low incidental solar radiation on the top of carrot canopy as

the major part of solar radiation was intercepted by the tree canopy when the crop was associated with ber trees.

There was a significant increase in the relative humidity within the crop canopy of carrot in case of underplanted crop. This may be attributed to lesser wind movement under the canopy of trees resulting in more buildup of humidity. The present findings are in conformity with the results reported by Reddy (1997) when radish was intercropped in proximity to ber trees,

Stomatal diffusive resistance was higher at mid day (12.00 hrs) compared to morning and evening hours, indicating more conductance during these hours. Sole crop recorded least stomatal diffusive resistance compared to intercropped carrot and underplanted carrot at all times. In the present investigation lesser stomatal diffusive resistance recorded during morning hours compared to afternoon lend support from the explanation given by Salisbury and Ross (1986), that stomatas of most plants open at sunrise allowing entry of CO₂ needed for photosynthesis during the day time and closing in gradual throughout the afternoon.

Transpiration was relatively higher during early hours (8.00 hrs) of the day and slowly decrease till late afternoon (16.00 hrs), irrespective of the cropping system. This is again related to the mode of opening and closing of the stomata during these hours.

5.4 Effect of INM practices of carrot on the performance of associated ber

The INM practices of carrot had a significant effect on the fruit yield of ber. Maximum fruit yield was observed when underplanting of carrot was taken up in ber followed by intercropping and least in sole ber. In underplanting situation neem cake with half recommended dose of NPK gave maximum fruit yield followed by vermicompost with half recommended dose of NPK and full recommended dose of NPK. Maximum availability of nutrients under these treatments in the tree basins might have contributed to the pool of nutrients available to the ber tree besides the normal dose of fertilizers applied to them. This additional supply and slow release of nutrients from the organic manures over entire period of fruiting might have resulted in higher fruit yield of ber. Relatively higher yields of intercropped ber compared to sole ber also indicates the ability of the tree's proliferating root system to gross nutrients from adjacent area in its favour and this was manifested in increased fruit yield (per tree and per hectare). However, the fruit size, quality and NPK content of ber leaf did not vary much under different treatments.

5.5 Economic evaluation of different cropping systems and INM practices

The gross monetary returns were in general higher when carrot was intercropped followed by underplanted in ber compared to either sole carrot or sole ber, irrespective of the INM practices adopted. The higher gross

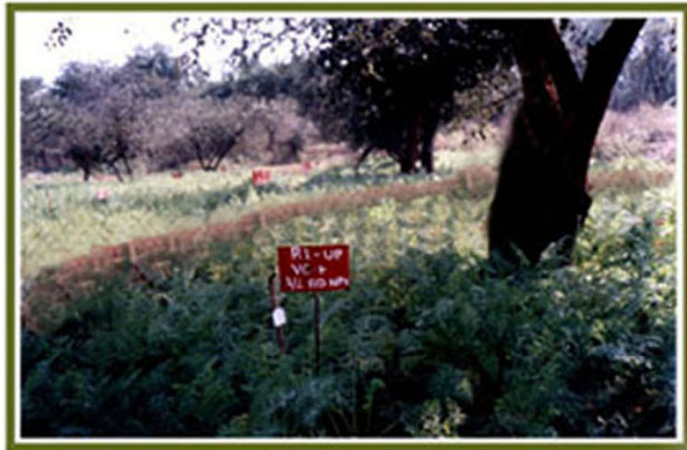
monetary returns under intercropping may be attributed to be relatively better performance of carrot compared to underplanting, due to less competition with the tree for above and below ground resources. The combined yield from the component crops (ber and carrot) gave higher monetary returns over sole cropping, which had only one component i.e., either ber or carrot.

The net monetary returns showed a favourable trend in respect of sole carrot compared to underplanted or intercropped carrot. This may be due to higher cost of cultivation of two components involved in the later case. Among INM practices, application of vermicompost with half of the recommended dose of NPK recorded the lower returns which may be attributed to the higher cost of the manure for the required dose (10 t ha^{-1}).

In general, the benefit cost ratio was found to be greater than unity in all treatments, indicating fairly higher returns on every rupee invested. However, these ratios were at higher side for sole carrot compared to either intercropped or underplanted carrot in ber, due to the low cost of cultivation in the former case. Higher benefit-cost ratio with 100 per cent recommended dose of NPK is again due to lower cost of inorganic fertilizers compared to organic manure.

The Income Equivalent Ratio (IER) in ber based cropping system was greater than unity indicating advantage of either underplanting or intercropping of carrot with ber over its sole cropping. Maximum IER of 1.82 in underplanted carrot with neem cake in combination with half of the

recommended dose of NPK indicated the yield advantage to be greater extent. Higher IER value of 1.68 reported by Syed Ismail (1994) when lemon grass was intercropped with ber at 240 kg N ha⁻¹. Reddy (1997) also reported on IER of 1.72 when radish was intercropped in ber at 120 kg Nha⁻¹. the higher the values in underplanted carrot in the present investigations may be due to the better competitive ability of the component crops and more particularly the under storied component (carrot which fared well even under reduced PAR availability to the crop. This may be explained in light of the findings of Cannel (1983) who opined that crops whose harvestable parts are vegetative tend to be less affected when grown in proximity to trees.



Underplanted
carrot in ber

Intercropped
carrot in ber



Sole carrot

Plate.3: Crop growth of carrot at 80 DAS under different cropping systems

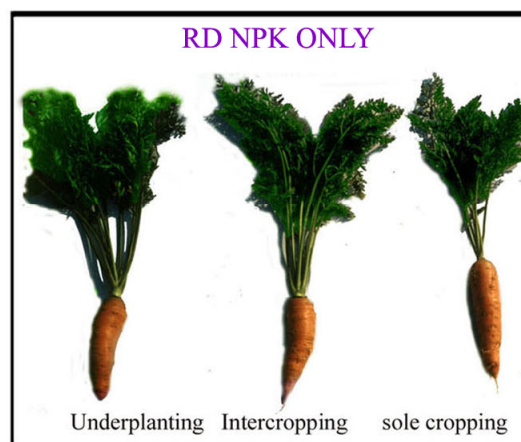
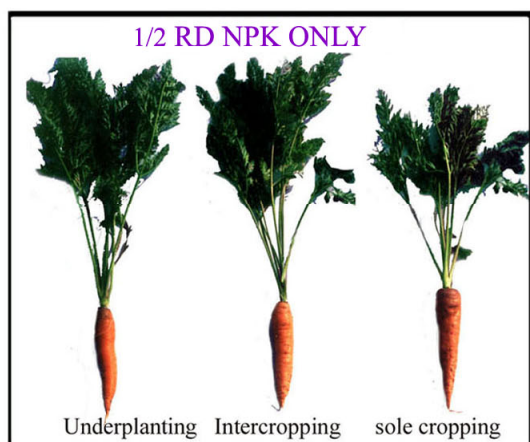
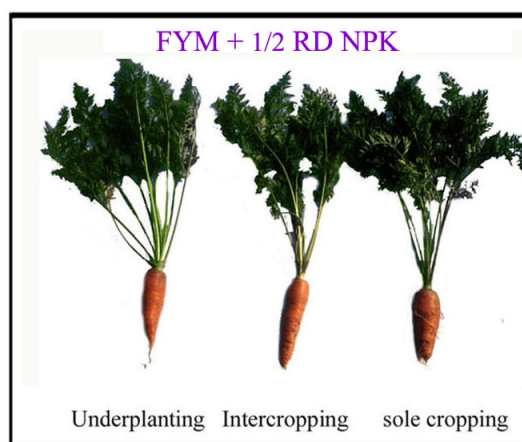
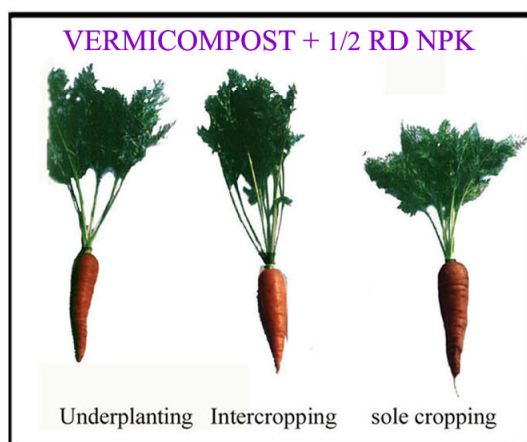
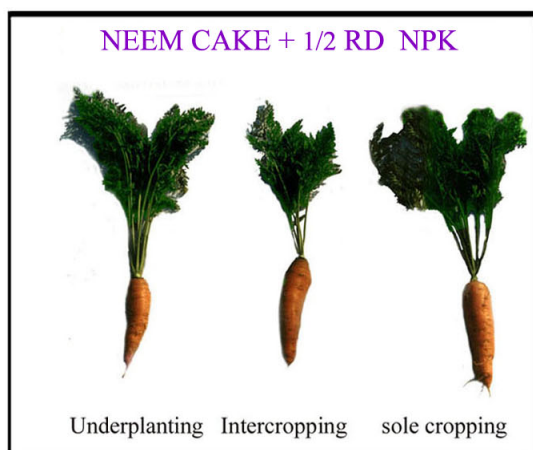


Plate.4: Shoot and root growth of carrot at harvest as affected by cropping systems and INM Practices



Underplanted
carrot in ber
(lanky growth due
to dense shade)



Intercropped carrot
in ber
(Moderate growth
in partail shading)



Sole carrot
(Good growth
in full sun)

Plate.2: Crop growth of carrot at 40 DAS under different cropping systems

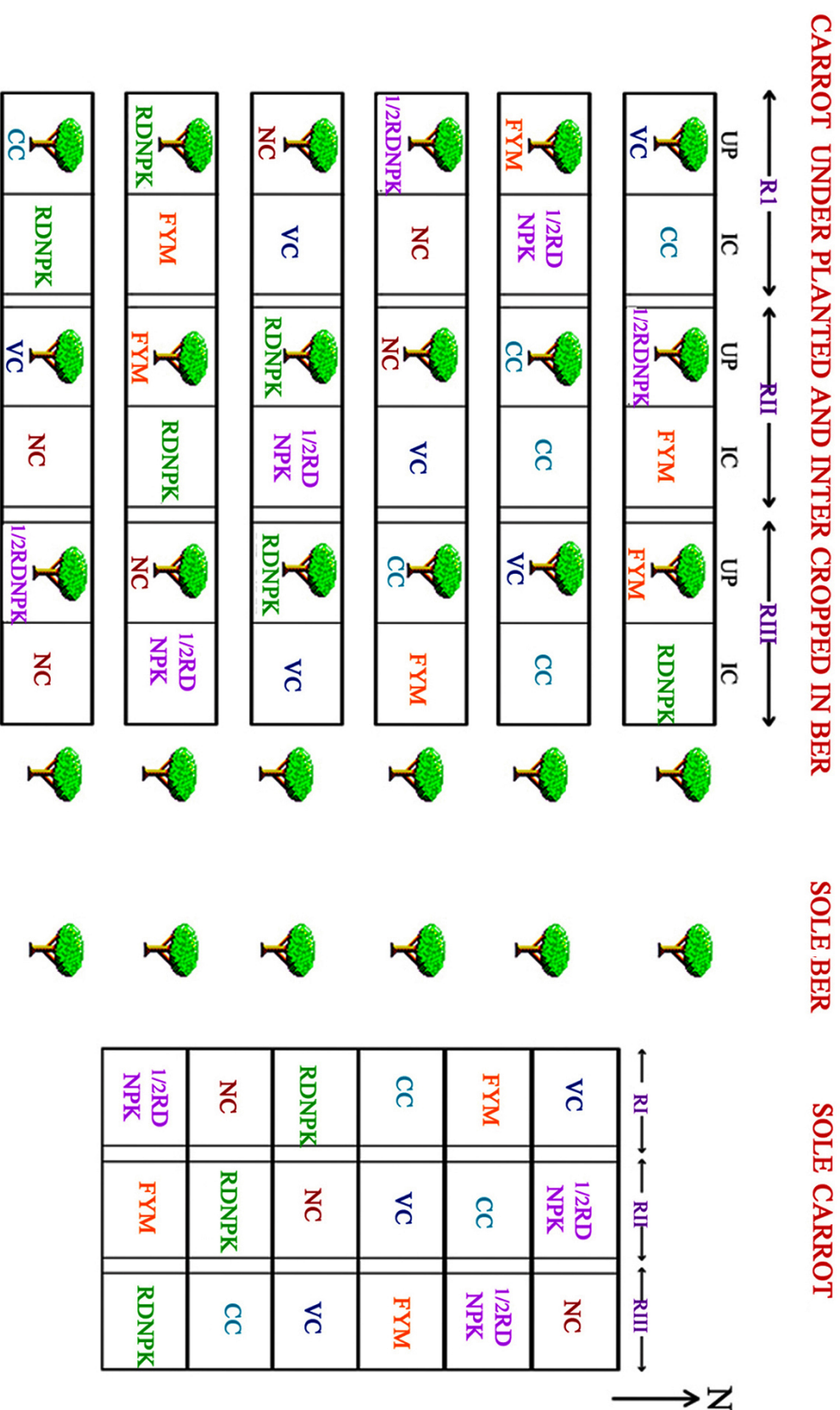


Fig.1: Layout plan of the field experiment under different cropping systems and INM practices.

CHAPTER – VI

SUMMARY

A field experiment on “Performance of carrot under different Integrated Nutrient Management practices in ber-based cropping system” was conducted during *rabi* season (October 2003 to February 2004) at Students Farm, College of Agriculture, Rajendranagar, Hyderabad. The experiment was laid out in a split plot design replicated thrice. The main treatments comprised of three cropping systems viz., underplanting, intercropping (in ber plantation) and solecropping of carrot. The sub treatments consisted of six INM practices to carrot viz., application of vermicompost @ 10 t ha⁻¹, neem cake @ 4 t ha⁻¹, castor cake @ 4 t ha⁻¹ and FYM 5 t ha⁻¹ in combination with half the recommended dose of NPK besides only half and full recommended dose (100:60:80 kg ha⁻¹ N, P₂O₅ and K₂O) of NPK. Carrot seeds of variety Early Nantes treated with bio-fertilizers (Azatobactor and Phosphobacterium @ 25 g kg⁻¹ each), were sown on ridges at a spacing of 30 x 5 cm in a plot of 4 x 4 m size within the interspaces of two ber trees for intercropping, in the tree basin for under planting and away from ber trees for solecropping in the same field. The results obtained in the present investigation are summarized below.

6.1 Plant height of carrot was significantly affected by the cropping systems at all stages of crop growth, maximum being in under planting followed by intercropping in ber and the least in sole

cropping. Among different INM practices, neem cake in combination with half recommended dose of NPK recorded higher plant height at all the stages except at 40 DAS.

- 6.2** Maximum root length of carrot was recorded under solecropping at all stage compared to intercropping and under planting in ber. Neem cake in combination with half the recommended dose of NPK improved root length over other organic manures but was on par with the full recommended dose of NPK only.
- 6.3** There was a linear increase in root girth of carrot from 20 DAS to 80 DAS in all treatments, maximum being in sole crop followed by intercrop and least in underplanted crop. Castor cake resulted in maximum root girth of 8.92 cm at 80 DAS.
- 6.4** Sole crop recorded significantly highest fresh weight of root compared to intercropped and under planted carrot. Castor cake in combination with half the recommended dose of NPK recorded maximum fresh and dry weight of root compared to other organic manures and fertilizers.
- 6.5** Sole crop recorded highest root yield (19.15 t ha^{-1}) over intercropped and underplanted carrot (12.63 and 10.02 t ha^{-1} respectively). Castor cake in combination with half recommended dose of NPK recorded maximum root yield (15.86 t ha^{-1}) but was on par with neem cake and vermicompost in combination with half

the recommended dose of NPK besides full recommended dose of NPK.

- 6.6** Shoot yield of carrot was not affected significantly with cropping systems. However, among different INM practices full recommended dose of NPK gave maximum shoot yield of 19.05 t ha⁻¹ which was on par with the organic manures in combination with half the recommended dose of NPK.
- 6.7** Shoot-root ratio was also significantly affected by cropping systems, underplanted carrot in ber registered the highest shoot-root ratio of 1.70 and least in sole crop (1.01). Neem cake in combination with of the recommended dose of NPK and only half recommended dose of NPK recorded maximum shoot-root ratio (1.47).
- 6.8** Carotene content of carrot was significantly higher in sole crop (4.22 mg/100g) over intercropped and under planted carrot (4.05 and 3.96 mg/100g, respectively). Neem cake application in combination with half the recommended dose of NPK to carrot resulted in significantly higher carotene content (4.42 mg/100g) compared to all other organic manures and fertilizers.
- 6.9** Maximum reducing, non reducing and total sugar content of carrot was recorded in sole crop followed by intercrop and least in underplanted carrot. Neem cake in combination with half the

recommended dose of NPK registered maximum reducing and total sugars, though the non reducing sugar content was higher with FYM in combination with half the recommended dose of NPK.

- 6.10** The TSS content of carrot was significantly higher in sole crop (13.09°Brix) followed by intercrop (12.37°Brix) and least in underplanted carrot (11.99°Brix). Among different INM practices neem cake in combination with half the recommended dose of NPK recorded higher TSS content (12.81°Brix).
- 6.11** The total chlorophyll content of carrot leaves differed significantly under different cropping systems, the highest in underplanted carrot (1.56 mg/100g) followed by intercropped and sole carrot (1.37 and 1.26 mg/100g respectively) which were on par. The INM practices had no significant effect on chlorophyll content of carrot leaves.
- 6.12** Nitrogen, phosphorus and potassium content of carrot was adversely affected in underplanted crop compared to sole and intercropped carrot in ber. Among different INM practices full recommended dose of NPK only recorded significantly higher N content (1.92%) while castor cake in combination with half of the recommended dose of NPK recorded highest P (0.30%) and K (2.89%) content.

- 6.13** The uptake of NPK by carrot crop was also significantly affected by cropping systems, highest with sole crop followed by intercrop and least with underplanted carrot. Maximum uptake of N was registered with full recommended dose of NPK only (30.98 kg ha⁻¹). Castor cake in combination with of the recommended dose of NPK recorded higher uptake of P and K compared to other organic manures and inorganic fertilizers.
- 6.14** The PAR availability on the top of carrot crop canopy was reduced to the extent of 57 and 30 per cent in underplanted and intercropped carrot respectively compared to sole crop during early hours (8.00 hrs). However, at mid day (12.00 hrs) the reduction in PAR was to the tune of 71 and 40 per cent in underplanted and intercropped carrot respectively.
- 6.15** Lower leaf temperature and increased relative humidity within the crop canopy of carrot was observed in underplanted compared to sole and intercropped carrot.
- 6.16** Underplanted carrot in ber recorded lower stomatal diffusive resistance and higher transpiration during early hours (8.00 hrs) and the trend was reversed by mid day (12.00 hrs).
- 6.17** The INM practices of carrot had a significant effect on fruit yield of ber. Neem cake in combination with half of the recommended

dose of NPK gave maximum fruit yield of ber in underplanting situation (38.3 kg tree⁻¹ and 5.93 t ha⁻¹).

- 6.18** The average fruit weight, fruit quality and NPK content of ber leaves was not affected by the cropping systems and INM practices to carrot.
- 6.19** The gross monetary returns were in general higher when carrot was intercropped with ber followed by underplanting compared to sole carrot or sole ber irrespective of INM practices adopted. However, the B : C ratios were at higher side for sole carrot compared to either intercropped or underplanted carrot in ber.
- 6.20** The Income Equivalent Ratio (IER) in ber based cropping system was greater than unity indicating advantage of either underplanting or intercropping of carrot with ber over its sole cropping. Maximum IER of 1.82 in underplanted carrot with neem cake in combination with half of the recommended dose of NPK.

From the present investigations it is concluded that growing of carrot in association with ber (intercropping/underplanting) with conjunctive use of organic manures (neem cake/castor cake) and chemical fertilizers (half the recommended dose of NPK) proved highly productive and remunerative. Though the full recommended dose of NPK only was also equally good in promoting growth and yield of carrot but it is not advisable considering its possible adverse effects on soil health and environment besides substantiality.

It is also concluded that, carrot can be grown in the entire orchard area covering not only the interspaces between grownup trees but also in the tree basins for effective utilization of available land without much reduction in yield and thereby increasing overall productivity and returns from the orchard.

Future line of work

1. Since growing of carrot as underplanted crop was successful besides intercropping, it is suggested to try carrot during summer in orchards taking the advantage of microclimatic ameliorations, wherever irrigation facilities are available to capture the market when it is high demand.
2. Performance of underplanted summer carrot may also be studied by staggering pruning dates of ber.
3. Organic manures and chemical fertilizers may be tried with and without bio-fertilizers to know the exact role of the later in enhancing root yield of carrot.

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

APPENDIX – II

Nutrient content of organic manures

Organic manure	N (%)	P ₂ O ₅ (%)	K ₂ O (%)
Vermicompost	3.00	1.0	1.50
Neem cake	5.22	1.08	1.48
Castor cake	4.37	1.85	1.39
Farm yard manure	0.75	0.20	0.50

Source : Chadha (2001).

APPENDIX – III

Cost of cultivation of carrot without manures and fertilizers

S.No.	Item	Rs. ha ⁻¹
1	Land preparation, cleaning, formation of ridges and furrows	1250
2	Formation of irrigation channels	680
3	Cost of seed	2200
4	Sowing of seed	680
5	Manure and fertilizer application	816
6	Earthing up and weeding	816
7	Regular irrigation	1020
8	Harvesting	3400
9	Removal of shoots, roots and cleaning of roots	1020
10	Grading and marketing	680
11	Miscellaneous	300
Total		12,862

APPENDIX – IV

Cost of cultivation of ber

S.No.	Item	Rs. ha ⁻¹ yr ⁻¹
1	Pruning	700
2	Ploughing (June-July : Interspaces), cleaning and hoeing of basins	1000
3	Plant nutrition	
	a). Cost of fertilizers	4614
	b). Cost of fertilizer application	680
4	Irrigation	680
5	Plant protection	
	a). Cost of pesticides	1600
	b). Cost of spraying	680
6	Harvesting, grading and marketing	3200
7	Miscellaneous	500
Total		13,654

APPENDIX – V

Treatment wise cost of cultivation of all components

Main/sub treatments	Cost of cultivation of carrot	Cost of cultivation of ber	Total
<i>Under planting</i>			
VC + 50% RD NPK	32428	13654	46082
NC + 50% RD NPK	28028	13654	41682
CC + 50% RD NPK	27228	13654	40882
FYM + 50% RD NPK	18078	13654	31732
50% RD NPK only	14428	13654	28082
100% RD NPK only	15994	13654	29648
<i>Inter cropping</i>			
VC + 50% RD NPK	32428	13654	46082
NC + 50% RD NPK	28028	13654	41682
CC + 50% RD NPK	27228	13654	40882
FYM + 50% RD NPK	18078	13654	31732
50% RD NPK only	14428	13654	28082
100% RD NPK only	15994	13654	29648
<i>Sole cropping</i>			
VC + 50% RD NPK	32428	-	32428
NC + 50% RD NPK	28028	-	28028
CC + 50% RD NPK	27228	-	27228
FYM + 50% RD NPK	18078	-	18078
50% RD NPK only	14428	-	14428
100% RD NPK only	15994	-	15994
<i>Sole ber</i>	-	13654	13654

APPENDIX – VI

Treatment wise cost of cultivation of carrot with manures and fertilizers

Main/sub treatments	Cost of cultivation of carrot without manures and fertilizers	Cost of manures and fertilizers	Total cost
<i>Under planting</i>			
VC + 50% RD NPK	12862	19566	32428
NC + 50% RD NPK	12862	15166	28028
CC + 50% RD NPK	12862	14366	27228
FYM + 50% RD NPK	12862	5216	18078
50% RD NPK only	12862	1566	14428
100% RD NPK only	12862	3132	15994
<i>Inter cropping</i>			
VC + 50% RD NPK	12862	19566	32428
NC + 50% RD NPK	12862	15166	28028
CC + 50% RD NPK	12862	14366	27228
FYM + 50% RD NPK	12862	5216	18078
50% RD NPK only	12862	1566	14428
100% RD NPK only	12862	3132	15994
<i>Sole cropping</i>			
VC + 50% RD NPK	12862	19566	32428
NC + 50% RD NPK	12862	15166	28028
CC + 50% RD NPK	12862	14366	27228
FYM + 50% RD NPK	12862	5216	18078
50% RD NPK only	12862	1566	14428
100% RD NPK only	12862	3132	15994

APPENDIX – I

Table 1: Weekly mean meteorological data during the crop growth period, 2003-04 (.2003 to 2004)

Std. week	Date	Temperature (°C)		Mean relative humidity (%)	Rain fall (mm)	No. of rainy days	Mean sun shine hours per day	Wind speed (km per hr)	Mean Evaporation (mm day ⁻¹)
		Maximum	Minimum						
45	Nov. 5-11	30.1	16.5	65.0	0.0	0	8.7	1.9	2.3
46	Nov.12-18	29.9	15.3	65.0	0.0	0	7.8	2.0	2.7
47	Nov.19-25	29.1	12.6	64.5	0.0	0	9.1	2.5	2.3
48	Nov.26-Dec.2	29.2	12.7	65.0	0.0	0	9.0	2.3	2.4
49	Dec. 3-9	29.3	9.5	53.0	0.0	0	9.3	2.1	2.4
50	Dec. 10-16	29.0	11.7	60.0	0.0	0	8.3	2.7	2.6
51	Dec. 17-23	28.5	10.0	58.0	0.0	0	9.2	2.1	2.9
52	Dec. 24-31	26.8	15.8	67.0	0.0	0	4.7	3.5	2.7
1	Jan. 01-07	28.1	12.5	64.5	0.0	0	8.3	2.9	2.3
2	Jan. 08-14	27.7	9.2	57.5	0.0	0	9.2	2.3	2.6
3	Jan. 15-21	31.1	11.9	57.0	0.0	0	9.8	2.5	3.4
4	Jan. 22-28	29.5	18.9	71.5	2.8	1	7.2	4.1	2.9
5	Jan.29-Feb.4	28.8	18.1	74.0	4.5	1	5.5	3.3	2.6