RESPONSE OF SELECTED OKRA [*Abelmoschus esculentus* (L.) Moench] CULTIVARS TO ROOT KNOT NEMATODE *Meloidogyne incognita* (Kofoid and White)

By

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(2014-11-150)

THESIS

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DECLARATION

I, Chandini S. M (2014-11-150) hereby declare that the thesis entitled **"Response of selected okra [*Abelmoschus esculentus* (L.) Moench] cultivars to root knot nematode *Meloidogyne incognita* (Kofoid and White)"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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Date: 17|07|2017

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CERTIFICATE

Certified that thesis, entitled **"Response of selected okra [*Abelmoschus esculentus* (L.) Moench] cultivars to root knot nematode *Meloidogyne incognita* (Kofoid and White)"** is a bonafide record of research work done independently by **Ms. Chandini S. M. (2014-11-150)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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Chandini S. M.

Dedicated to my beloved

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is an important vegetable crop, popularly known as "bhendi" or "lady's finger" in India with hermaphrodite flowers belonging to the family Malvaceae. It is a biannual crop grown in three seasons in the tropical and subtropical regions throughout the world. The medicinal, nutritional and industrial value of okra fruits makes it a promising vegetable crop globally. It is rich in protein, vitamin A and B; the predominant elements found in the vegetable are K, Mg, Ca, Na and Fe (Saifullah and Rabbani, 2009).

The global production and area under okra is reported to be 78,96,300 t and 11,48,000 ha. Out of which India contributes 73.25 %, Nigeria 12.10 %, Sudan 3.24 %, Iraq 1.92 % and Pakistan 1.43 %. Highest productivity is from Egypt (12.5 t ha^{-1}) followed by Saudi Arabia (13.3 t ha^{-1}). Andhra Pradesh is the leading state in India, which has a production of around 11,84,200 t followed by West Bengal (862100 t), whereas in Kerala it was found to be very low (APEDA, 2017).

Okra cultivation in India is mainly hampered by the attack of different pests and pathogens. Among them, plant-parasitic nematodes pose a formidable pest problem in okra, brinjal, tomato and potato. The estimated loss in yield of okra due to plant parasitic nematodes is 20.40 per cent (Sasser, 1987).

About 176 species of nematodes have been found associated with the rhizosphere of okra in India. Among them plant parasitic nematodes attacking okra includes root knot nematodes *Meloidogyne* spp., cyst nematode *Heterodera* spp., reniform nematode *Rotylenchulus reniformis* (Linford & Oliveira), stunt nematode *Tylenchorhynchus* spp., spiral nematode *Helicotylenchus* spp., lance nematode *Hoplolaimus* spp., lesion nematode *Radopholus similis* (Thorne) and stem and bulb nematode *Ditylenchus* spp. Root knot nematode, *Meloidogyne* spp.

13

is the major group of nematodes attacking okra in India (Mahajan *et al.*, 1986; Sakhuja and Jain, 2001).

Root-knot nematodes infest a wide range of crop plants and are markedly damaging the vegetable crops throughout the world (Youssef *et al.*, 2012). Among the reported species of *Meloidogyne*, the four most commonly occurring species are *Meloidogyne incognita*, *M. javanica, M. arenaria* and *M. hapla*. Different species of root-knot nematodes damage more than 2000 species of cultivated plants. Root-knot nematodes are reported to cause annual losses in tropics up to 22 % in okra, 23 % in brinjal, 29 % in tomato and 24 % in potato (Sasser, 1979).

Nematodes like *Meloidogyne incognita* (Kofoid and White), *R. similis* and *Heterodera* spp. are widely distributed in Kerala and are found associated with the major vegetable crops grown. Okra is attacked by two important genera of nematodes, *viz., M. incognita* and *R. reniformis.* Root knot nematode, *M. inognita* significantly reduce yield by 9 to 29 per cent under field conditions in Kerala (Sheela and Anitha, 1997).

In Kerala, mostly okra is grown under homestead condition or as intercrop in plantations. This makes a favourable condition for the development of insect pests and diseases. In addition to insect pests and diseases, plant parasitic nematodes are also playing a major role in limiting the successful cultivation of okra. The nematode damage on the crop mainly depends on the type of farming system followed. The extent of damage is very less under situations of multiple cropping and also in fields where crop rotation is practiced. Severe nematode infestation is noticed under intense farming, monocropping and also in fields, where crop rotation is practically nil.

Okra is found to be highly susceptible to the attack of root knot nematode, *M. incognita* (Noling, 2002). The infestation by root knot nematodes results in the formation of "galls" or "root knots" in the root system of the plants and this affects the normal functioning followed by disruption in the uptake of water and nutrients. Nematode infested plants are generally stunted, show signs of nutrient deficiency, defoliation, reduction in flowering and fruiting and appear unhealthy. In case of severe infestation of *M. incognita* in okra results in an yield loss upto 32 per cent (Jain *et al*., 2006).

Several methods have been developed for the management of nematode infestation. Use of chemical nematicides is the most effective, which brings about 80 per cent reduction in nematode population. Recently, application of chemical control for nematodes has been declined due to its inherent toxicity to nontarget organisms, crop residue in fruits, their persistence in environment and high cost benefit ratio. Therefore, there is an immense need to find more alternative nematode management strategies in okra.

Host resistance is an important component of integrated nematode management. Use of cultivar resistant to *M.incognita* is one of the best alternatives, which is specific, environmentally safe, economically feasible and comparatively better yielders than susceptible cultivars. Cultivation of resistant cultivars is limited and only a few okra cultivars are reported with resistance to root knot nematodes. A number of screening studies have been conducted in okra both under pot and field conditions. Most of the cultivars are reported to be susceptible to root knot nematodes (Hussain *et al*., 2014).

Keeping this in view, the present study was aimed to screen the selected okra cultivars against root knot nematode, *Meloidogyne incognita* and to elucidate the biochemical basis of resistance.

15

Review of literature

2. REVIEW OF LITERATURE

Screening of okra germplasm against root knot nematodes will provide valuable information on the source of resistance. Several screening studies on okra against *Meloidogyne incognita* were conducted in Kerala Agricultural University during 1991- 2016 under field conditions. Okra germplasm such as IC 9825, IC 9857, IC 169404, IC 329364, EC 169357, EC 16939, EC 169334, EC 169357, EC 329369, EC 329371, K 117306 and K 198370 were reported to be resistant against *M.incognita* (Sheela *et al.*, 2005).

Literature pertaining to the pathogenicity and crop loss due to *Meloidogyne* spp. on okra, screening of okra cultivars against *Meloidogyne* spp. and the biochemical basis of resistance are presented below.

2.1. PATHOGENICITY AND CROP LOSS DUE TO *Meloidogyne* spp. IN OKRA

An investigation was carried out by Ganaie *et al.* (2011) to study the pathogenicity of *M. incognita* on okra under greenhouse condition. Significant reduction in plant growth parameters *viz.*, shoot and root length, fresh weight and dry weight due to nematode infestation was reported. The rate of multiplication in the population of various developmental stages recorded from the roots revealed that okra is a good host for root knot nematode *M. incognita*.

Studies on impact of nematode population on growth parameters of okra cv. Punjab Selection revealed that increasing nematode inoculum levels reduced the growth parameters. A higher reduction in shoot and root length and root weight were observed at 8000 juveniles per plant with 44.65, 42.10 and 43.78 per cent, respectively. Significant increase in number of egg masses and galls were recorded at all inoculum levels but maximum galls and egg masses were recorded at a level of 8000 juveniles per plant (Hussain *et al.*, 2011).

17

Pathogenicity test conducted against root-knot nematode, *M. incognita* on okra revealed that highest reduction in biometric parameters was recorded in the plants inoculated with 8000 J_2/plant. Significant reduction in plant length was recorded at and above 2000 J_2/plant. At this level, symptoms like thinly spread foliage with small leaves, yellowing and premature shedding of leaves and stunting of plants were observed. Further it was observed that the reduction in plant growth *i.e.* length, fresh and dry weight were decreased between the inoculum levels of 4000 and 8000 J_2/plant (Shabab and Sharma, 2011).

Singh *et al.* (2011) conducted a study on the effect of different levels of root knot nematode, *M. incognita* on okra and found that with increasing levels of the inoculum from 20 to 2000 second stage juveniles per plant of *M. incognita*, there was a corresponding increase in percentage reduction of plant growth characters. The highest reduction was recorded at 2000 juveniles per plant preceded by 1000, 500 and 100 juveniles. Number of egg masses, adult females and soil population were significantly increased with increase in inoculum level. Highest gall index was also noticed at inoculum levels of 2000 and 1000 respectively.

Mukhtar *et al.* (2013) evaluated pathogenic potential of *M. incognita* on okra at population densities of 0, 1000, 2000 and 4000 juveniles (J_2) per plant inoculated after 2nd, 3rd, 4th and 5th week of emergence. Significant reductions in fresh shoot weight and plant height were recorded at all inoculum densities. Highest decrease was recorded at an inoculum level of 4000 J_2/plant at all plant ages. Maximum egg masses and galls were recorded in plants inoculated with 4000 juveniles per plant after two weeks and the minimum was recorded with inoculation of 1000 juveniles per plant after five weeks. The production of egg masses and galls was observed to be directly proportional to the inoculum levels.

18

2.2. SCREENING OF OKRA AGAINST *Meloidogyne* spp.

Several researchers were screened okra cultivars for resistance to root knot nematode *M.incognita* over the last four decades. Rao and Singh (1977) tested the susceptibility of thirty four varieties/selections of okra against *M. incognita* and found that all the varieties/selections were found to be susceptible towards the nematode.

Jain and Bhatti (1984) screened thirty five varieties of okra for their reaction towards *M. incognita* under greenhouse condition and found that the variety IC 23592 was resistant with gall index of 1. Remaining varieties were highly susceptible with root knot index > 5.

Pot culture experiment was conducted to evaluate the resistance of 146 okra cultivars to *M. incognita*. Only three cultivars namely IC 52314, 118/82-74 and 92/82-2 were found to be resistant with root knot index of 1.6, 1.1 and 1.8 respectively. Remaining 142 cultivars with root-knot index ranging from 4-5 were rated as either susceptible or highly susceptible (Darekar and Ranade, 1990).

Sharma and Trivedi (1990) screened twenty six okra cultivars for their resistance towards *M.incognita.* None of the cultivars exhibited resistance towards the nematode, but cultivar Pusa Sawani was reported as the most susceptible variety with higher reduction in yield.

Singh *et al.* (1993) evaluated twenty four okra varieties/cultivars for their reaction to *M.incognita.* Three varieties/cultivars KS 381, KS 114 and KSL 380 were reported to be resistant with root knot index <1, five cultivars were found to be moderately resistant with root knot index of 3 and remaining accessions were found to be susceptible and highly susceptible.

Ramakrishnan *et al.* (1993) studied the response of fifteen okra varieties/ cultivars against *M.incognita* race 3 both under pot culture and field conditions. All the accessions were reported to be susceptible or highly susceptible with gall index of >5.

Six exotic cultivars and six local ecotypes of okra were screened for their reaction towards *M. javanica*. Ecotype Balady Green and cultivar Clemson Spineless were reported to be resistant with higher yield of 4.04 t/feddan and 5.21 t/feddan. Remaining ecotypes except Nobaria Selection were rated as either moderately resistant, resistant or highly resistant (Hussien *et al.*, 1994)

Jain and Gupta (1996) screened 24 okra cultivars for their reaction against *M.incognita* in a pot culture experiment with local highly susceptible variety as check. None of the cultivars were recorded as highly resistant or resistant. Seven genotypes *viz.*, IC-31340, IC-24908, Sel-33-1, Sel-314, IC-185542, IC-24908, and IC-23592 showed moderate resistant reaction with root knot index 3. Remaining varieties were found to be susceptible with root knot index >4.

Sharma and Singh (1996) screened ten varieties of okra *viz.,* RO 3, 87-5, XHE 002, Pusa Sawani, XHE 001, Arch-2, COH 3, Nathshobha 101 and BO 2 against *M.incognita.* All the okra varieties were found to be susceptible to *M.incognita* with root knot index >5.

Sharma and Trivedi (1996b) evaluated ten okra varieties for their reaction against *M.incognita* in a pot culture study. All the varieties exhibited susceptible reaction towards *M.incognita* with reproduction factor >1 and root knot index 5.

Das and Sinha (1998) screened twenty okra varieties (IC-4378, 4507, 8991, 10252, 10262, 10265, 11533, 12933, 18960A, 18973A, 18975, 22232, 22237, 23594, 23626, 24135, 27878, 29119A, 31033D, 45994 and Pusa Sawani) collected from National Bureau of Plant Genetic Resources, New Delhi against root knot nematode, *M. incognita.* Among the twenty okra varieties screened none of the varieties were found to be resistant or moderately resistant. Eighteen varieties were highly susceptible to root knot nematode with root knot index 5-6 and two varieties IC-89991, IC-27878 were reported to be susceptible with root knot index 4.0.

Forty-seven plant introductions (PI) of okra were evaluated for resistance by Thesis *et al.* (1998) against *M.incognita* race 3. None of the accessions were 20 reported with resistance or highly resistance reaction. Gall index was severe in all the accessions ranging from 4.4.to 5.0. Highest gall index was observed in PI 120833 followed by PI 177236 and PI 123451. All the screened accessions were found to be highly susceptible to the nematode with maximum number of eggs per gram of fresh root ranging from 76,000 to 130,000.

Eighteen germplasm and three okra varieties were screened for resistance against *M.incognita* by Rekha and Gowda (2000) under greenhouse conditions. None of the germplasm/varieties were reported as resistant. Germplasm such as AROH-10, HOE-202, VLC-1, AROH-9, VB-9101 and IIHR-91 and variety Arka Anamika were reported as susceptible with root knot index 4. Remaining germplasm such as D-1-87-5, HYOH-2, AROH-8, VB-9103, HHR-58, Padmini, VRO-3, DVR-2, HHR-91, HHR-24, DRP-4, DOV-91-4, P-7, HYOH-1 and variety Arka Abhay were rated as highly susceptible with root knot index 5.

Sheela *et al.* (2006) screened 293 varieties/ lines of okra for their reaction against *M.incognita* and found that three lines NBPGR-TCR 770, NBPGR-TCR-852 and NBPGR-TCR- 937 with root gall index of 2.0 were resistant. Out of 293 varieties/ lines, only 123 lines were found moderately resistant with a gall index of 3.0. Remaining 167 varieties/lines were susceptible or highly susceptible with gall index of > 5.0.

Kumar and Jain (2011) studied the response of thirty five wild type genotypes of okra procured from Regional Station of NBPGR, Thrissur against *M.incognita* and found that none of the okra genotypes was resistant. Two genotypes *viz.*, IC 140970-A and IC-203863 were found to be moderately resistant with 11-30 galls/egg mass. Genotypes IC-140983, IC-90478, IC-277033, IC-141010, IC-90386, IC-140995, IC-470737, IC-141056, IC-90505, IC-141014, IC-140972, IC-90503, IC-141002, IC-90504, IC-470732, IC- 470742, IC-141040, IC-141003, IC-90530, IC-470748, IC-141015, IC-470737, IC-141056, IC-140985 were reported to be susceptible with 31-100 eggs/gall.

21

Mohanta and Mohanty (2012b) evaluated fifty six okra varieties/ germplasm for their reaction against root knot nematode, *M. incognita* and were ranked as per the 1-5 root gall index for screening. Among the fifty six varieties/germplasm, none of them was found resistant. Five accessions *viz.,* IC 111471, IC 128372, IC 169482, IC 411698 and IC 433686 were reported as moderately resistant with root knot index 2-3. Seventeen accessions were categorised as highly susceptible with gall index of 4-5.

Gad *et al.* (2013) screened three okra cultivars Hyper Dokki-1, Hyper Dokki-2 and Ismaily to analyse their reaction towards *M.incognita* in Egypt. Plant growth parameters such as total plant fresh weight expressed as the maximum reduction percentage (32.41) for cv. Hyper Dokki-1, whereas minimum value of 21.81 percentage for cv. Ismaily. Variety Ismaily was scored as moderately resistant with root gall index 2.2 and minimum nematode population in both soil and root. Okra cv. Hyper Dokki-2 was scored as susceptible to *M. incognita* infestation with root knot index of 3.3 and their percentage reduction in total plant fresh weight was 24.44 per cent.

Singh *et al.* (2013) screened ninety four genotypes of okra for their response towards root knot nematode *M. incognita* under greenhouse condition. Local recommended okra variety Pusa Sawani was included for comparison as susceptible check. Data revealed that none of the genotypes was resistant to root knot nematode. However, thirty genotypes were reported as moderately resistant and remaining thirty four highly susceptible and twenty as susceptible.

Twelve okra cultivars were screened for resistance by Mukhtar *et al.* (2014) against *M.incognita* under field conditions. None of the cultivars was reported to be highly resistant. The cultivar 'Sharmeeli' was found to be highly susceptible with more than hundred galls on roots and showed highest yield reduction among the cultivars evaluated. The cultivars Anmol and Sindha were reported as susceptible with 71-100 galls. The cultivars Sanam, Ikra-2, Arka

Anamika, Dikshah and Ikra-1 were found to be moderately resistant with 11-30 galls.

Karajeh and Salameh (2015) evaluated the response of thirty-seven landraces and accessions of okra against *M. javanica* in Jordan. International landraces : TOT 581, Egypt Green, TOT 7963, TOT 2739, Palestine landrace , TOT 7957, TOT 7346, USA red and some Jordan landraces (Jordan 12, Jordan 34, and Jordan 169) were rated as moderately resistant with root gall index (RGI) 2. Landraces Egypt red, Jordan 3, Jordan 8, Jordan 48, Jordan 49, Jordan 84 , TOT 1767, India Prabhani, India Sade, TOT 7159, TOT 7164, TOT 7101, TOT 7102, TOT 7343, TOT 7345 and TOT 7966 were rated as moderately susceptible with RGI 3. Land race TOT 7343 was observed with maximum fresh shoot weight 4.67 g/plant, while minimum was observed in Jordan 42 with 2.23 g/plant.

Khan *et al.* (2015) evaluated 126 accessions of okra for their reaction towards *M. incognita.* Three accessions IC 022232, IC 039140 and IC 117074 were reported as resistant with < 10 root galls/plant. Remaining accessions were categorised into moderately resistant, susceptible and highly susceptible with more number of root galls/plant.

Hussain *et al.* (2016a) evaluated the response of twenty eight okra cultivars to *M.incognita* under greenhouse conditions and found that none of the cultivars were highly resistant or resistant. Cultivars including Bamya Akkoy, Bamya Yalova, Bamya Sultani, Perbhani Kranthi, Clemson Spineless, Punjab Selection, Pusa Green, Sabzperi, Green Wonder, Superstar, Sanam, Arka Anamika, Ikra-3 and Ikra-4 were reported as moderately resistant with minimum reductions in shoot weight and root-shoot length. Cultivars Ikra-1, Ikra-2, Sabzperi and China red were rated as susceptible with significant reduction in shoot weight and root-shoot length with respect to their control. Maximum percentage reduction in shoot weight, shoot length and root length were observed in cultivar Pusa Sawani. Maximum number of galls per root system was observed in cultivar Perbhani Kranthi 361 followed by Pusa Sawani 124. Cultivar 19236

23

was reported with minimum number of galls per root whereas cultivar Pusa Sawani was reported with higher J_2 production per 100 cc soil.

Odeyemi *et al.* (2016) conducted an experiment to determine the pathogenicity of root knot nematode *M. incognita* on okra accessions and their degree of resistance to the nematode. Reduction in plant height of okra plants due to *M.incognita* infestation ranged from 13.69 to 75.64 per cent, fruit weight from 12.96 to 53.29 per cent and shoot weight from 13.69 to 13.69 per cent. Accessions NHGB/10/048, NG/SA/DEC/07/0528, NHGB/09/057, NG/SA/DEC /07/0208 and NG/TO/JUN/09/007 were tolerant whereas NG/AA/SEP/09/038, NHGB/09/055 and NG/SA/DEC/07/498 were susceptible to *M.incognita.*

2.3. SCREENING OF OTHER VEGETABLE CROPS AGAINST *Meloidogyne* spp.

2.3.1. Brinjal

In a pot culture study, Haider *et al.* (2001) evaluated reaction of thirty-four brinjal germplasm against *M. incognita* race-2. None of the cultivars was found to be highly resistant. Four varieties including KS-224, 71-19, Vijay and Annamalai were reported as resistant with root knot index 2 and 3-10 galls/plant. Twenty six cultivars/lines were reported to be moderately resistant with 11-30 galls/plant and root knot index 3. Remaining cultivars/lines were rated as either susceptible or highly susceptible.

A pot culture study was conducted to evaluate twenty brinjal varieties for their reaction towards *M.incognita* and found that variety Vijay and Annamalai were resistant with root knot index of range 0.7 and 0.8. These varieties were observed with minimum number of galls per plant as 10.33 and 12.66 respectively. Four varieties *viz.,* Rajendra, Azad Hybrid, Syamala and BR-112 were reported as moderately resistant with root-knot index 1.51, 1.42, 1.44 and 1.57 respectively. Two varieties No.81 and VNR-125 were found to be moderately susceptible having root gall index 2.86 to 3.01. Seven varieties *viz.,* 24

Azad kranti, Green Round, Aruna, NS-317, Navkiran No.23, Sakura-371 and VNR-60 were reported to be susceptible exhibiting root-knot index as 3.4, 3.45, 3.8, 3.43, 3.3, 3.26, and 3.01(Nayak and Sharma, 2013).

Singh *et al.* (2013) screened nine varieties of brinjal (Small long white, BRSPS 14, IVBL 9, IVBHL 54, Nassappe, Pant Rituraj, DBL-24, Uttara and Punjab Sadabahar) and five varieties of tomato (Punjab Chhuhara, IIVR Sel.1, NF31Sb8, VFN 8 and NF 31) for their reaction to *M.incognita*. Brinjal varieties Small long white, DBL-24 and Punjab Sadabahar were found resistant with root knot index of range <1 and the remaining varieties were found susceptible.

Beegum *et al.* (2014) conducted a net house study for the evaluation of resistance with thirteen brinjal cultivars against *M. incognita*. Among them the variety Uttora was found moderately resistant and the remaining were scored as susceptible or highly susceptible. Highest number of egg masses/ root system was reported in two varieties BARI Begun-10 (438.40) and BARI Begun-4 (417.60). Lowest was reported in cultivar Uttora (80.80). Maximum gall formation in root system was found in variety Deshi (9.00) and the lowest was reported in variety Uttora (2.60).

Das and Mohanty (2014) screened twenty five varieties of brinjal for their reaction towards root knot nematode, *M.incognita* and found that varieties Utkal Madhuri and Kanta Baigen were resistant with gall index of range 1-2 and minimum eggmass/plant of range 6.2-8.2. Ten varieties including Round Brinjal, BB-7, Bhanajanagar Local, Keonjhar Local Long, Athagarh local, Black beauty, Rajendra Annapoorna, Rajendra Baigen, Muktakeshi and BB 48 were found as moderately resistant with gall index of 3. Remaining thirteen varieties were found to be susceptible with gall index of 5. Variety Kendrapara was observed with maximum number of egg masses per root system 75.40 followed by B-B-13 (47.60).

Devi and Sumitha (2015) screened fifteen germplasm of brinjal against root knot nematode *M. incognita* and found that none of the germplasm was found resistant. It was observed that four germplasm *viz.,* JB 09-01, JB 09-12, JB 10-14 and JB 01-16 were susceptible and the remaining eleven germplasm were highly susceptible. Highest root knot index was observed in highly susceptible varieties GB 09-16-02, GB 09-02-02 and JB 10-18.

Nayak and Pandey (2015) screened 100 varieties/cultivars of brinjal towards their resistance against *M.incognita*. Twenty varieties/cultivars reported to be resistant with gall index of the range 1.1 to 2.0. Fifty eight varieties/cultivars were found to be moderately resistant with gall index of 2.1 to 3.0. Twenty five varieties were found highly susceptible with highest gall index of 4.1 to 5.0. Susceptible & highly susceptible cultivars expressed maximum reduction in plant height when compared with that of control. Formation of giant cells and galls in the roots of both resistant and susceptible brinjal varieties had shown decrease in shoot weight (34.08 %) and root weight (31.67 %).

2.3.2. Tomato

Khan and Khan (1991) screened thirty six tomato cultivars for their reaction towards *M.incognita* and found that two varieties VFN-Bush and VFN-8 were resistant to *M. incognita.* Ten accessions, namely Pusa-120, Calmart VFN, Punjab-6, NR-7, EC173898 (72T6), EC173897 (Cal-Mart), EC173896 (Kewalo), CLN363BCIF-2-167-1-0, CLN363BC-F, -190-1-0, CLN363BCIF-344-0-0 and CLN299BCIF-4-1-4-1-1-0 were found to be immune without any galls in the root.

Thirty five tomato varieties/lines/hybrids were screened against root-knot nematode, *M.incognita* including the highly susceptible local variety, Solan Gols as control. The results indicated that four varieties HOE-606, NDT-9, PT-203 and Hisar-1 were scored as resistant with gall index of range 1.0-1.8, two varieties/lines NDT-3 and NDT-44 scored moderately susceptible with gall index 2-3 and the remaining eight varieties/lines/hybrids were susceptible with gall index 3-5 (Khan and Rathi, 2000).

Devran and Elekcolu (2004) conducted a screening study on reaction of thirteen lines of tomato under pot culture experiment in Turkey. Only two lines 26

AB12 and AB13 were reported to be susceptible to *M.incognita* with gall index 6 and 5. Remaining thirteen lines were reported to be resistant with gall index 1.

Forty seven germplasm of tomato germplasm were tested for their reaction to root knot nematode *M.incognita* (Kamalvanshi *et al.*, 2004). Eight germplasm such as 8307, 8302, 8785, 7014, 8308, 8202, 1098 and 6802 were scored highly resistant with root gall index 1. Six germplasms (4609, 6536, 5902, 7006, 8713 and 6404) were scored resistant with gall index 2 and four germplasm (KS176, 6806, 8725 and 6512) as moderately resistant with root gall index 3. Remaining germplasm were scored as either susceptible or highly susceptible reaction with root gall index 4 and 5.

Pathan *et al.* (2004) conducted a study on reaction of seven tomato germplasm against *M. incognita* and found that none of the cultivars was found to be highly resistant to *M. incognita*. Significant reduction in growth parameters were recorded in highly susceptible cultivars Peshawari and Roma.Two varieties Long Italy and Royal Holland were recorded as resistant and the remaining three varieties Salos Holland, Money maker and Top Holland were reported with moderately resistant reaction.

Sharma *et al.* (2004) screened one hundred and thirty varieties of tomato against *M.incognita* race-1 and found that none of the varieties were immune to the nematode. Two lines (7418 and 130053) were found to be resistant and the lines 126004 and 378682 were observed as moderately resistant having gall index of range 1.0 and 1.16. Two varieties/lines Mangala and 310954 were found to be moderately susceptible against *M.incognita* race-1 with gall index 2.5. Eight varieties were susceptible with gall index 3.3- 4.3. Rest of the varieties/lines were highly susceptible.

Nine varieties/lines were evaluated for their response against root knot nematode *M.incognita* under greenhouse conditions. Variety Sel-2 was taken as susceptible check. All the varieties/lines were scored as susceptible and highly susceptible with root knot index range 4-5. Varieties CO3, DVRT2 and KT 10 were observed with maximum number of galls/plant and number of egg masses/10g root. Plant height, fresh shoot weight and fresh root weight were observed to be high in variety CO3 followed by KS 227. Minimum growth parameters and nematode population in soil and root were reported in varieties Sel-2 and Sel-3 (Devi *et al.*, 2007).

Kaur *et al.* (2010) conducted a pot culture experiment on evaluation of 119 numbers of tomato line/varieties for their resistance to *M.incognita* and found that only eight lines including 8-2-1-2-5, 1-6-1-4 , PNR-7, Hisar Lal (NT-8), EC 119197, EC 31802, EC 531804, NDTTNR-76 were resistant having root gall index of range 0.1 to 1.0. Seven lines (NT-7, NDTTNR-77, CR2-5-1, EC 16788, EC 521049, EC 529081, GT 1003-B16-1) exhibited moderately resistant reaction having root gall index between 1.1 to 2.0 and fifteen lines were found to be moderately susceptible having root gall index between 2.1 to 3.0. Among the remaining lines, 36 lines were found susceptible showing root gall index between 3.1 to 4.0 and 53 lines were found to be highly susceptible.

Rai *et al.* (2010) conducted a screening study in pots to evaluate the response of thirty five genotypes of tomato against *M.incognita.* None of the genotypes were categorized as immune or highly resistant. Genotype EC-520070 was reported as moderately resistant with a gall index of 3 and genotype Meghalaya Local was reported as slightly resistant with >40 galls and gall index 4. Remaining thirty three genotypes were reported as susceptible with gall index 5.

Kamran *et al.* (2011) conducted a study on reaction of seven tomato genotypes to *M. incognita* under greenhouse condition and found that all the genotypes were susceptible to nematode infection. Tomato cv. PB-8 and PB-28 were susceptible with gall index of 4 while all the other five genotypes namely Round-41, Riogranade, Round small-127 and PB-47 were highly susceptible with gall index of 5. Variety Round-41 recorded maximum number of galls per root system followed by variety Round-21. Higher reduction in shoot weight was observed in variety PB-28 and it was lower in variety Round-41.

Thirty three tomato genotypes were screened for resistance to root knot nematode *Meloidogyne* spp. in both under pot culture and field experiment with different inoculum levels 100, 500, 1000, 1500 and 2000 egg/plant. Two varieties Beef Master and Tomato Mongal T-11 were found highly resistant to *Meloidogyne* spp. and also exhibited the lowest root knot index of 3.75 and 3.25. Variety Burpee Roma was reported as moderately resistant with root knot index 4.00. Rest of the varieties exhibited susceptible to highly susceptible reaction towards *Meloidogyne* spp. with root knot index 6.25 to 8 (Jaiteh *et al.*, 2012).

Khanzada *et al.* (2012) evaluated reaction of five tomato varieties namely Anmol, Roma v.f., Gola France, Roma Holland and Sunehra for their reaction towards root knot nematode *M.incognita*. Maximum number of egg masses per root system and root knot index was recorded in inoculated plants of Roma v.f followed by Roma Holland, Golla France, Sunehra and Anmol. Total number of galls/plant was higher in inoculated plants than control plants. Higher root weight was recorded in variety Roma v.f rated as highly susceptible and lesser root weight was observed in variety Anmol rated as resistant.

Reddy *et al.* (2016) screened thirty-two genotypes of tomato against *M.incognita* under net house condition. Out of thirty-two varieties, two varieties namely LA 2823 and H-88-78-1 were recorded as immune to *M.incognita* without any galls and two accessions LA 3471 and Hisar Lalit were recorded as resistant with mean gall index of range 1 and 2. Remaining twenty accessions exhibited susceptible reaction with mean root gall index of range of 4-5.

2.3.3. Chilli

Pandey and Trivedi (1990) screened ten local cultivars of *Capsicum annuum* L. and one *C. frutescens* L. against *M.incognita*. Each variety exhibited varying degree of resistance towards the nematode. Only one variety Pusa Jwala was reported as resistant with lower number of galls/plant (1-50). Two varieties 29

Mandore local-l and Mandore local-2 were reported as moderately resistant with 51-100 galls/plant. Remaining varieties were categorised as moderately susceptible, susceptible and highly susceptible with more galls/plant root.

Malhotra *et al.* (2012) conducted a screening study on five chilli *Capsicum annuum* cultivars against *M. incognita*. Five cultivars *viz.*, Pusa Jwala, Pusa Sadabahar, PC-1, Mathania Local, and Jaipur Local were inoculated with 1000 infective juveniles per plant. None of the cultivars were reported to be immune and the variety Pusa Jwala exhibited moderate resistance to *M.incognita*. Varieties Pusa Sadabahar and Mathania local reported as moderately susceptible with Root knot index 3. Maximum number of galls (42.33) and root knot index (4) was reported in Variety PC-1 and is found to be susceptible.

Hwang *et al.* (2016) evaluated 102 commercial cultivars of chilli for their resistance towards *M. incognita*. Thirty two cultivars were found to be resistant to *M.incognita* with minimum number of egg masses per plant. Fourteen cultivars were found to be moderately resistant to *M.incognita* and the remaining fifty six cultivars were rated as susceptible.

2.4. SCREENING OF OTHER CROPS AGAINST *Meloidogyne* spp.

Rao and Krishnappa (1995) conducted a study on reaction of released cultivars of chickpea to *M.incognita* under field conditions. Out of 13 cultivars screened, 11 varieties exhibited susceptible reaction while Annegiri -1 and Chaffa were found to be highly susceptible.

Sixty six mulberry cultivars including 48 indigenous, 8 hybrids and 12 exotic genotypes were screened for their reaction against *M. incognita* under pot culture experiment. Among the 48 indigenous varieties screened, none of them was resistant to *M. incognita* while eleven genotypes *viz.*, Assambals, S-30, S-1, S-1096, RFS-135, ACC-115, S-1531, MR-2, Punjab local, Almora local and Belidevalaya showed moderately resistant reaction with 2.2 to 3.0 galls and 2.0-3.0 egg mass index. The number of galls/plant recorded from 7.78 to 32.74 and eggmass/plant from 4.45 to 16.0. Fourteen varieties namely Himachal Local, S- 30

796, S-642, ACC-217, S-61, S-14, ACC-151 Mendalaya, ACC-217, S-146, S-36, ACC-152 were also found to be moderately resistant with 3.1-4.6 gall index and 3.1-3.4 egg mass index. Of the remaining 25 varieties, 11 were moderately susceptible with 4.0-5.0 gall index and 3.6-4.0 egg mass index. Rest of the varieties were susceptible and highly susceptible (Govindaiah *et al*., 1996).

Eleven varieties/germplasm of carrot (American Beauty, Early Nantes, G.S 86, Indian Long Red, Nantes, Niligiri Local, Pusa Jamalagur, Pusa Kesar, Section-1, Section-5 and Zino) were screened for their response against *M.hapla.* All the eleven varieties/germplasms were found susceptible to *M.hapla* to varying degrees. However the highest root knot index was scored with 'Early Nantes' (4.61) and the lowest with Pusa Jamalagur (3.33). Root knot indices of 4.33, 4.20, 3.80 and 3.73 were reported with the varieties American Beauty, Section-5, Indian Long Red and Section-5 respectively. Variety Nilgiri Local (DC-25) registered the highest yield of 34.7g per pot which was significantly superior to other varieties followed by Indian Long Red and Selection-1 with 30.0 and 28.7g carrot per pot respectively (Sivakumar and Vadivelu, 1996).

Nugent and Dukes (1997) screened five cultivars/lines of melon *Cucumis melo* L. against *M. incognita*. Each line was inoculated with different levels of inoculum such as 0, 500, 1000, 2000 and 5000 and compared with a highly resistant species *Cucumis mutifera*. (Line C 800). Lines Chilton, Gulf Coast, Georgia 47 and Planters Jumbo were rated as moderately resistant whereas lines 140471 and 183113 were highly resistant to *M.incognita.*

Different varieties/lines of pigeon pea, chickpea, lentil and field pea were screened for their response against *M.incognita* in pot culture condition. Out of 141 varieties of chick pea, only eight varieties were found moderately resistant. Rest of the chickpea lines were found susceptible and highly susceptible to *M.incognita*. Out of 55 varieties/lines of field pea screened against root knot nematode, only Pant P-74 was recorded as resistant and eight varieties/lines were shown susceptible or moderately resistant reaction while remaining were susceptible or highly susceptible. Forty one varieties of lentil were screened against *M. incognita* and the results indicated that none of them was highly resistant or resistant. Out of 70 varieties of pigeon pea screened against *M.incognita,* Ak-101, Ma-6, JBP-1024, Bahar, MA-3, NAD-1, Birsa Arhar, Azad, T-7 and Mal-13 were moderately resistant, C0-6 as susceptible and VKG-141151 was highly susceptible, whereas rest of the varieties were highly resistant or resistant (Simon and Das, 2000).

Bora *et al.* (2004) evaluated reaction of 282 green gram varieties against *M.incognita.* All the varieties screened were reported to be susceptible or highly susceptible. Out of 282 varieties, seventy four varieties including Ganga-1, COGG-902, IC-10495, PLM-30, ML-95, PLM-1057, PUSA 105 and RMG-381 were found to be susceptible (gall index 3.1-4.0) to root knot nematode. The remaining varieties were reported to be highly susceptible with gall index of 4.1-5.0.

Deshmukh *et al.* (2004) screened twenty grape varieties against root knot nematode, *M .incognita* under glass house conditions. Out of twenty varieties, only three varieties Black Chamba, Degrasset and Dogridge were found to be resistant with mean number of galls per plant 6.7, 3.0 and 2.7 respectively and root knot index of 2.0. Two varieties Pandhri Sahebi and Champanel were moderately resistant with root knot index of 3.0. Rest of the varieties were found to be susceptible and highly susceptible.

Pot culture study was conducted to identify reaction of seven gherkin cultivars against root knot nematode, *M.incognita.* The cultivar PS 64487 scored (maximum shoot length (105.33 cm) with more number of leaves (22.33), more number of fruits (9.00) with higher shoot weight (27.37 g) followed by Sandesh and Asgrow. Cultivar PS 64487 and Stemora scored lowest number of galls (57 and 34 respectively). Cultivar PS 64487 expressed significant increase in plant growth parameters and decline in development and multiplication of nematodes. All the cultivars scored root knot index of 3.33-5.0 reflecting their susceptibility

32

to *M.incognita*. Higher root knot index was observed in cultivar Asgrow (5.00) followed by Royal calypso (4.67) and Ajax F1 (4.33) and lower in Stemora (3.33) and PS 64487 (3.67) (Praveen and Gowda, 2004)

128 varieties of black gram and 102 varieties of green gram were screened for their response towards *M.incognita*. Out of 128 varieties of black gram, 46 varieties were found to be susceptible and remaining 82 to be highly susceptible. None of the varieties of black gram was resistant to *M.incognita*. Out of 102 varieties of pigeon pea, 14 were reported as highly resistant, 57 as resistant and 27 as moderately resistant. Four varieties were found to be susceptible (Rahman *et al.*, 2004).

Sharma *et al.* (2006) evaluated reaction of twenty three selections of field pea against *M.incognita* under greenhouse conditions. Strong negative correlation was observed between plant growth parameters with root knot index. Among the 23 selections tested three selections *viz.,* HFP 990173, Selection Pant P-25 and HFP-0219N were reported as resistant with root knot index 1. Remaining accessions were found to be with moderate resistance or susceptible ones.

Sixteen mulberry varieties/genotypes were screened for their reaction against *M.incognita* and exhibited differential reactions against root knot nematode. Variety S-13 was reported as moderately resistant and variety S-34 as susceptible with root knot index 3.30 and 4.02 respectively. Rest of the varieties were highly susceptible with root knot index ranging from 5.00-5.75. Highest root knot index (5.75) was recorded in highly susceptible variety AR-10 and it was observed that the final nematode population in the roots of variety AR-10 was at least 97 times higher than the initial inoculum (Naik *et al.*, 2010).

Mukthar *et al.* (2012) studied the reaction of fifteen cucumber (*Cucumis sativus*) cultivars against *M.incognita*. All the cultivars varied significantly in causing reduction in growth parameters with respect to their control. It was found that none of the cultivars was recorded as highly resistant or resistant. Only one cultivar Long Green was reported as resistant with root knot index 2.0, minimum 33 galls/root (3-10) and minimum reduction in growth parameters. Four cultivars namely Mehran, Mirage, Thamin-II and Royal Sluis were reported as highly susceptible with maximum galls/roots. Maximum reduction in shoot weight (44.67) was observed in cultivar Royal Sluis and minimum in Long Green (3.3).

Kakati and Mohanta (2013) screened eighteen cultivars of cucumber (*Cucumis sativus* L.) and found that none of the cultivars were ranked as resistant. Only one cultivar EC-641913 was reported as moderately resistant with root knot index 2.4. Eleven accessions including EC 641908, Cucumber Green Long Special, EC 641912, Malini, EC 641920, Bankim, EC 641927, Cucumber No.243, EC 641934, Nandini and EC 641934 were reported as susceptible with root knot index 3.4-4.0 range. Five cultivars EC 641925, Cucumber NS-408, Improve Noori, Kalyan, Debstar and Alisa were found as highly susceptible.

Devi *et al.* (2014) tested the reaction of twenty eight germplasms of mungbean against *M. incognita* race-2 under greenhouse conditions. Out of 28 genotypes, 24 were susceptible and four were highly susceptible to *M.incognita* race-2. No resistant or moderately resistant genotypes were recorded.

The reactions of eighty-seven genotypes of common bean (*Phaseoulus vulgaris* L.) were screened against *M.incognita* by Bozbuga *et al.* (2015) under growth chamber conditions in Turkey. The genotypes were categorised based on the root knot index, root galling severity and number of egg masses/plant. Among the eighty seven genotypes only one genotype Sehirali was found immune with root knot index 1 and zero egg mass production. Four genotypes TR 42164, Seleksiyon 5, Seker Fasulye, and Fas-Agadir-Suk-1 were categorised as highly resistant with root knot index 2.0 and minimum egg mass production per plant. Remaining eight genotypes were moderately resistant, twenty intermediate, thirteen moderately susceptible, twelve highly susceptible and ten susceptible. The highest root knot index of 5.0 was observed in genotype Sirik Ayse Kulcal.

Punithaveni *et al.* (2015) evaluated reaction of seven cultivated and wild cucurbitaceous rootstocks and two cucumber scions (hybrid and variety) against 34 the root knot nematode *M incognita*. Minimum fresh and dry root weight, lower root knot index and egg mass per gram of root was observed in *Citrullus colocynthis* and *C. metuliferus* and these root stocks were rated as resistant. Root stocks of *C. maxima, C. ficifoilia, Cucurbita moschata* and *Luffa cylindrical* were reported as moderately resistant with root knot index 3.0. Green Long variety and NS 408 hybrid of cucumber were observed to be highly susceptible to *M. incognita* with root knot index of 5.0.

A pot culture evaluation was conducted to analyse the reaction of twenty muskmelon genotypes against *M.incognita.* None of the genotypes expressed resistant reaction towards *M.incognita.* But eight genotypes were found highly susceptible, eleven genotypes exhibited susceptible reaction to *M.incognita,* whereas one genotype was moderately susceptible. Reproduction factor was observed to be >1 in all the accessions screened. Infestation of *M.incognita* decreased shoot length and root length in all the genotypes as compared to control (Singh *et al*., 2015)

Screening of twenty fenugreek *Trigonella foenum-graecum* varieties against root-knot nematode *M. incognita* under pot condition revealed UM-72 and UM-178 as resistant; UM-3 and Rmt-365 as tolerant; UM-2, UM-7, UM-19, UM-86, UM-118, UM-135 and UM-354 as susceptible while UM-12, UM-46, UM-85, UM-90, UM-97, UM-147, UM-185 and UM-202 were highly susceptible to *M. incognita* (Tariq *et al*., 2016).

35

2.5. BIOCHEMICAL BASES OF RESISTANCE IN CROPS AGAINST NEMATODES

Biochemical traits of the host plants play a potential role in the host-nematode interaction. Root knot nematodes are obligate parasites and they are able to disturb the host metabolism. The change in biochemical processes of infested host as a consequence of disrupted metabolism decides whether the host is susceptible or resistant to the nematode attack. The effects of such biochemical characters of host plants on the infestation by nematodes have been studied by a number of workers.

Development of giant cells induced by the root knot nematode *Meloidogyne javanica* in tomato (variety Pan America) roots has been studied under controlled growth conditions and the ultrastructure and histochemistry of these structures have been examined. The giant cell wall is a thick, irregularly surfaced structure which contains all the normal polysaccharide components of a cell wall. The cytoplasm is rich in protein, RNA, mitochondria, proplastids, golgi bodies and a dense endoplasmic reticulum. Presence of more number of golgi bodies in the giant cells of galled roots is responsible for the increase in polysaccharide content in galled root exudates of tomato (Bird, 1961).

The total sugars in the leaves, roots and root-knots of *Acalypha indica* infested with *M.incognita* were studied and compared with the uninfested plant. It was observed that the sugar values were lesser in the infested plant compared to the uninfested plant. In the infested root system itself, the root-knots showed lesser amount of sugar compared to the non-knoty portions adjacent to the root-knots (Kannan, 1968).

Dropkin *et al.* (1969) investigated the effect of exogenous plant growth regulating substances on the early stages of the host parasite interaction between *M.incognita* in tomato seedlings. In the absence of these substances, approximately 73 per cent of larvae that entered roots of susceptible plants

36

showed growth, none induced necrosis and nearly all induced formation of galls. In roots of resistant variety, only 4 per cent of the larvae developed, 88 per cent induced necrosis of host cells and only 29 per cent induced gall formation. Exogenous application of cytokinins shifted the reaction of the resistant plants towards the susceptible reaction. Exogenously supplied kinetins at 0.4 and 0.8 Mm allowed 55 to 57 per cent of the nematodes to grow, decreased the incidence of necrosis to 32 and 31 per cent and increased gall formation to 73 to 65 per cent.

Host-parasite relationships of *Pratylenchus penetrans* and *Meloidogyne incognita acrita* were compared on three closely related cultivars of tomato: Nemared (resistant), Hawaii 7153 (moderately resistant) and B-5 (susceptible). They found that larvae of these nematodes never penetrated the resistant variety of tomato due to some sort of inhibition provided by phenolic compounds. Chlorogenic acid was reported as the major phenolic compound in healthy tomato roots. Variety Nemared contained the highest concentration of the chlorogenic acid and B-5 recorded the lowest (Hung and Rohde, 1973).

Estimation of ortho-dihydroxyphenols and phenols from roots of three tomato varieties *viz.,* Nemared (resistant), Chiogrande (moderately resistant) and Marglobe (highly susceptible) inoculated with *M.incognita* was made. Highest concentration of ortho-dihydroxy phenols and phenols were registered both in inoculated and uninoculated plants of Nemared and lowest in Marglobe. Accumulation of these compounds was rapid in Nemared than in Chiogrande and Marglobe varieties. Hydroquinone and Phloroglucinol were detected only in Chiogrande and Nemared. These compounds were not detected in the Marglobe variety (Masood and Husain, 1976).

Investigations on influence of *Meloidogyne incognita* and *Heterodera cajani* on carbohydrate content were carried out in two cowpea varieties such as Pusa Barsati and Barsati Mutant. Infestation by *M.incognita* showed an increase in non-reducing sugars in shoots of both varieties and an increase in reducing sugars in Pusa Barsati whereas the total sugar content of the roots decreased.

Infestation with *H.cajani* decreased the reducing sugar concentrations in the shoots of both varieties and increased non-reducing sugar content in the shoots and decreased in the roots. Accumulation of non-reducing sugars in shoots of *H.cajani* infested plants was more marked than in shoots of *M.incognita* infested plants. Nematode infection increased the total carbohydrate content and affected the ratio of reducing /total soluble carbohydrate (Sharma and Sethi, 1976).

Veech and McClure (1977) investigated the role of post infectional increase in concentration of terpenoid aldehydes in roots of cotton variety Auburn (resistant) to *M. incognita.* The susceptible variety Deltapine 16 showed a slight increment of this parameter compared with resistant ones. Gossypol and other terpenoid aldehydes were having role in defence against insects and plant-pathogenic fungi. Similarly, it was assumed that these compounds could reduce the multiplication and development of nematodes also.

Noel and McClure (1978) found that there was an increased specific activity of 6-phosphogluconate dehydrogenase and peroxidase enzymes in *M. incognita* infested cotton. The resistant cultivar (Clevewilt 6-3-5) showed higher enzyme activity than the susceptible one (M8).

A number of biochemical parameters including phenols, starch, reducing sugars, proline, free amino acids and protein were estimated in the healthy and infested roots of brinjal inoculated with *M.incognita*. An increase in amino acids, protein and proline content was recorded in infected roots over that of healthy roots. Proline increased to 20 percentage after 90 days of inoculation. A decrease in reducing sugars and starch was recorded in the infected roots, while phenol content increased in infected roots than their counter parts (Singh *et al*., 1978).

Ganguly and Dasgupta (1979) conducted a study on sequential development of peroxidase and IAA-oxidase activities in two tomato varieties *viz*., SL-120(resistant) and Pusa Ruby (susceptible) inoculated with *M. incognita.* Higher enzyme activity was observed in inoculated plants of both the varieties. The disc electrophoretic analysis of peroxidase activities isolated from inoculated 38 plants revealed that both resistant and susceptible plants responded to parasitic invasion by synthesising new peroxidase isozymes. IAA-oxidase activities in both the varieties consisted of two anionic isozymes having peroxidase activities.

Peroxidase and IAA-oxidase activities were investigated in roots of *M.incognita* infested plants of resistant and susceptible tomato varieties by subjecting the crude extracts to a series of steps. Partially purified enzymes with high specific activities were obtained towards the final step. A purified preparation of IAA-oxidase activities from the inoculated plants was the existence of IAA-oxidase system in the resistant variety which has more activity than that of susceptible variety. Enzyme preparations from inoculated, resistant and susceptible varieties were catalytically and kinetically distinct from their healthy counterparts (Ganguly and Dasgupta, 1980).

A study was conducted to compare the levels of peroxidase and polyphenol oxidase activities in the roots of vegetables like tomato, okra, brinjal and bitter gourd infested with *M.incognita*. The activity of peroxidase was much higher than that of polyphenol oxidase in the roots of the four vegetable crops tested. Inoculated plants of okra and bitter gourd contain more enzyme activity than others. Infested plants of okra contained 1.5 EU/100mg polyphenol oxidase and it was absent in healthy plants. Infested okra plants contain more peroxidase (46.6 EU/100 mg) than healthy plants (37.2 EU/100 mg). The dry matter content was significantly higher in healthy plants than the inoculated plants of all the four tested vegetable plants (Ahuja and Ahuja, 1980).

Giebel *et al.* (1982) reported that active or post infectional resistance was based on plant tissue hypersensitivity to nematode infection. The host-parasite interaction stimulated definite biochemical reactions in the host that caused histological changes *i.e.* host cell necrosis. This necrosis developed around the nematode, walling it off and either delaying development or causing the nematode to die especially in case of endoparasitic sedentary nematodes.

Ganguly and Dasgupta (1983) observed considerable increase in total sugar in brinjal plants inoculated with *M.incognita*. Higher sugar level in infected tissues may be considered as a result of complex plant nematode interaction, which includes the hydrolysis of sucrose and the utilisation of simple sugar by the nematode.

Mahajan *et al.* (1985) reported the nematicidal activities of a number of phenolic compounds including monohydroxy, dihydroxy and trihydroxy compounds, quinones and aromatic acids such as transcinnamic acid and their effect on egg hatch of *M. incognita.* Ethyl gallate, pyrogallol, 2-OH napthoic acid and transcinnamic acid were found to be highly toxic with mortality percentage greater than 95 and maximum suppression of egg hatching achieved by Naringenin.

Malik *et al.* (1989) investigated nematicidal activity of various substituted phenols *viz.,* phenoxyacetic acid esters and hydrazides against second stage juveniles of seed-gall nematode (*Anguina tritici*), root knot nematode (*M. javanica*) and pigeon pea cyst nematode (*Heterodera cajani*). They found that phenols with electron donating substituents, particularly the chloro-substituted phenols are more active than those with electron withdrawing substituents.

Melakeberhan *et al.* (1990) investigated the concentration of reducing and non-reducing sugars in the infested roots of grape cultivars French Colom-bard (susceptible) and Thompson Seedless (moderately resistant). Nematodes did not affect the concentration of reducing sugars, but the concentration of non-reducing sugars increased in French Colom-bard and decreased in Thompson Seedless which indicated that there was more translocation of photosynthates to the feeding sites of the susceptible than to those of the resistant cultivars.

Molinari (1991) estimated the peroxidase activities with different substrates, ascertained the effects of root knot nematode *M.incognita* infestation on resistant and susceptible tomato cultivars. Activity of isoperoxidase and cellular locations were induced differentially in susceptible and resistant cultivars 40 by *M.incognita*. Nematode infestation remarkably elevated syringaldazine oxidase activity in cell walls of resistant cultivar. Isoperoxidase is involved in the final step of lignin deposition in plants. Contrarily, the susceptible cultivar responded to *M.incognita* infestation with an increase in cytoplasmic PPD-PC oxidase and which is involved in ethylene production; no variation in cell wall isoperoxidase was recorded. IAA oxidase activity was increased in resistant plants after nematode inoculation, whereas in susceptible plants this activity was inhibited.

Mahajan *et al.* (1992) evaluated a wide range of phenolic compounds for their nematicidal activity against *M. incognita*. Out of 55 phenolic compounds analysed, eleven compounds recorded high activity towards juveniles of *M.incognita*. The presence of ortho or para quinone group was associated with high nematicidal activity. Coumarin as well as meta-hydroxyl groups also induced high activity against nematode. Juglone and Coumestrol recorded with maximum activity against nematode.

Ganguly *et al.* (1993) studied the variation in enzyme activities of tomato varieties inoculated with *M.incognita* and found that the percentage of peroxidase activity in infested susceptible variety increased with time and infection. Peroxidase activity in resistant variety increased in the initial stages of infection, but decreased subsequently from 50 to 26 per cent. The activity of superoxide dismutase was found to be higher in susceptible variety (25-90%) than the resistant variety (7-50 %).

Biochemical changes occurred in okra roots infested with root knot nematode *M.incognita* was estimated after 30, 60, 90 days of inoculation. Quantitative analysis of various biochemical parameters in both less susceptible (Punjab-7) and highly susceptible (Pusa Sawani) were compared over their healthy counter parts. Infested roots of all ages scored a decrease in total sugars than their healthy plants. The reducing sugars expressed an increasing trend in infested roots of both the okra cultivars. Maximum increase of 44.47 percentage and 35.53 percentage of total sugar was recorded in Pusa Sawani and Punjab-7 41 respectively. With an increase in the age of the plants there was a corresponding increase in phenol content in healthy as well as infected roots of both the cultivars. The peroxidase activity was higher in infested roots of Punjab-7 (100 %) than Pusa Sawani (90%) after 90 days of inoculation (Sharma and Trivedi, 1996a).

Gopinatha *et al.* (2004) reported the histopathology of root knot infected moderately resistant and susceptible tomato plants. A tremendous increase of total insoluble polysaccharides, total protein and nucleic acid were observed in infested plants of moderately resistant cultivars than their healthy counterparts.

Studies on sequential development of phenol, polyphenol oxidase, phenylalanine ammonia lyase and lignin- like polymers were carried out in differential host plants (cotton cv. Deltapine and tobacco cv. NC-95) and their susceptible hosts (cotton cv. H-777 and tobacco cv. FCV Special). All the inoculated plants were observed with faster and early accumulation of these defence parameters than uninoculated ones, whereas the inoculated plants of susceptible hosts showed a gradual and delayed accumulation in their defence reactions (Swan *et al.*, 2004).

Krishnamoorthy *et al.* (2005) observed that *Helicotylenchus multicinctus* resistant banana hybrids *viz.*, H-201, H-02-08 and cultivars *viz.*, Anaikomban, Ambalakadali, Pisang Lilin and Eraichivazhai showed higher content of reducing sugar, orthodihydric phenol, bound phenol and phenylalanine ammonia lyase activity than susceptible cultivars.

Pot culture experiment was conducted to study the biochemical changes associated with resistance reaction against root-lesion nematode and root knot nematodes on five varieties of banana *viz.*, Nendran (AAB), Robusta (AAA), Pisang Jari Buaya (AA), Karthobiumtham (AAB) and *Musa balbisiana* (BBB). Maximum peroxidase activity and highest protein concentration was recorded in *cvs.* Robusta and Nendran whereas minimum was recorded in *Musa balbisiana*, Karthobiumtham and Pisang Jari Buaya. The activity of polyphenol oxidase was 42 reduced in infected plants of Nendran and Robusta but increased in Pisang Jari Buaya and *Musa balbisiana*. The Phenyl ammonia lyase (PAL) activity was significantly lower in Nendran and Robusta compared to other three varieties. The phenolic accumulation increased by 56% in Nendran whereas only 2 % increase in Karthobiumtham after nematode infestation (Sundararaju and Suba, 2006).

Eight genotypes of chickpea were evaluated for their reaction against root knot nematode *M.incognita*. All the tested varieties were reported to be moderately resistant except Pusa 362 which was susceptible. Peroxidase activity in the shoots of different cultivars of chickpea revealed that moderately resistant varieties exhibited higher enzyme activity. The maximum activity was observed in Pusa 256 and the minimum in Pusa 362 (Chawla and Pankaj, 2007).

Kavitha *et al.* (2008) reported the biochemical interactions of 24 phase I and 19 phase II generation banana hybrids against *P. coffeae* and exhibited higher contents of total phenol, OD phenol and lignin in resistant hybrids than susceptible ones. Histological studies also proved the presence of more phenolic and lignified cell in the resistant/tolerant hybrids.

Hofmann *et al.* (2008) reported that *Heterodera schachtii* induced specific syncytial feeding sites in the roots of *Arabidopsis thaliana* from where it withdrew all required nutrients. They demonstrated that the syncytia store carbohydrates by starch accumulation. Roots of inoculated plants showed massive starch accumulation in syncytia, whereas levels of starch in control roots were low. A tremendous increase of starch content occurred in 10 days old syncytia, showing levels of starch ten times higher than in non-infested roots.

A study on sugar transporter activity across the plasma membrane of syncytia developed due to infestation by *H. schachtii* was carried out by Hofmann *et al.* (2009). Analysis of soluble sugar pools revealed that the sugar transporters are specifically expressed and active in syncytia, indicating a profound role in inter and intracellular transport processes. Expression of three up-regulated (STP12, MEX1, and GTP2) and three down-regulated genes (SFP1, STP7, and 43

STP4) was analysed in the syncytia and found that the most up-regulated gene (STP12) have direct role in development of nematodes.

Nayak and Mohanty (2010) studied the biochemical changes in brinjal variety Pusa Purple Long inoculated with *M.incognita*. Among the various amino acids identified, eight amino acids were found to be common in both healthy and inoculated plants. The higher peroxidase activity was observed in nematode inoculated sample than their healthy counter parts. Reduced percentage of organic acids and total chlorophyll contents were observed in inoculated samples than healthy ones. However, an increase in amount of crude protein nitrogen and total sugar contents was observed in the infested roots. Higher concentration of various amides and aminoacids were observed in inoculated samples than healthy ones.

Das *et al.* (2011) reported the activities of enzymes like peroxidase, polyphenol oxidase and phenylalanine ammonia lyase and total phenol contents in banana roots were higher in *M. incognita* resistant genotypes like H-516 and H-531 than susceptible ones.

Korayem *et al.* (2011) evaluated the biochemical basis of reaction of 10 sugar beet genotypes against *M.incognita*. There was a significant increase in the activity of total phenol, peroxidase, polyphenol oxidase, catalase, phenyl alanine ammonia lyase and superoxide dismutase in inoculated plants than the uninoculated plants of both resistant and susceptible genotypes. These increased enzyme activity indicate the role of enzymes in defence against pests and pathogens.

Sundharaiya *et al.* (2011) studied the biochemical response of nine tomato genotypes inoculated with *M. incognita.* Three resistant genotypes including variety Hiasr Lalit , cross HN2 X CLN 2123A and the parent HN2 were reported with maximum root phenol content, peroxidase activity and polyphenol oxidase activity. These genotypes were also observed with higher acid phosphatase activity, root ascorbic acid content and IAA oxidase activity. Likewise the same genotypes were observed with lower root knot index (1.0-2.0). Lower enzyme activity and higher root knot index were observed in susceptible genotypes LCR 2 & CO 3.

Vaitheeswaran *et al.* (2011) reported that the pathogenic impact of *M. incognita* was reflected with low sugar level, elevated protein and lipid levels and reduced total energy content in infected tissues of *Hibiscus cannabinus.* The root-knot nematode infection induces increased protein concentration at initial stages of infection, which corresponds to resistance of nematode invasion during formation of root knots in infected plants

Kumar *et al.* (2012) reported the biochemical basis for resistance to mixed population of *P. coffeae* and *R. similis* in *in vitro* derived mutants of banana cv. Robusta (Cavendish- AAA) and Rasthali (Silk- AAB). They found that higher quantity of total phenol, tannin, lignin, peroxidase, polyphenol oxidase, phenylalanine ammonia lyase and ascorbic acid oxidase in resistant (Ro lm V4 6-1-1 and Si lm V4 10-5-3) and moderately resistant (Ro lm V4 6-2-1) mutants than the susceptible ones.

Mohanta and Mohanty (2012a) reported changes in various biochemical and physiological parameters like total sugar, total phenol, peroxidase, crude protein, chlorophyll and activity of peroxidase and catalase in okra variety L.B.H-55 inoculated with *M. incognita.* There was an increase in total phenolic content by 36.67 per cent, total sugar by 42.21 per cent, and catalase by 27.41 per cent and peroxidase by 16.67 per cent after 45 days of inoculation in healthy plants over their control plants. But a per cent decrease in content of total protein (39.89), total chlorophyll (10.39) and nitrogen (38.58) was noticed in infested than their healthy counter parts.

Syncytial feeding sites developed due to *H. schachtii* contain high levels of sugars that can be taken up by the nematodes. Nematode feeding site detected with most elevated sugar and starch levels. Starch acts as an intermediate storage, compensate sugar levels and sugar demands occur during the different phases of nematode feeding and development (Cabello *et al.*, 2013). 45

An increased activity of antioxidants like peroxidase, polyphenol oxidase, superoxide dismutase, dehydro ascorbate reductase esterase and monohydro ascorbate reductase were noticed in *M. incognita* resistant tomato cultivars (Hisar Lalit, PNR- 7) than susceptible ones (Punjab Varkha Bahar-1 and Punjab Varkha Bahar- 2). The intensity of isozyme bands of peroxidase and esterase was more in resistant than the susceptible ones (Chawla *et al.*, 2013).

Changes in biochemical parameters after nematode inoculation were studied in four varieties of tomato, two susceptible *i.e.* Punjab Varkha Bahar-1, Punjab Varkha Bahar-2 and two resistant *i.e.* Hisar Lal and PNR-7. The total phenolic content of different tomato genotypes were increased after inoculation of root knot nematode compared to that in their respective uninoculated varieties. The total phenol content was higher in the resistant varieties after inoculation with root knot nematode, whereas susceptible varieties showed a gradual decrease in phenolic compounds after inoculation. Resistant varieties Hisar Lal showed highest phenolic content *i.e.* 697 mg/ 100 g fresh weight in roots at 20 days after inoculation (Choudhary *et al.*, 2013).

A study was conducted by Kaur *et al.* (2013) to analyse the biochemical changes of ten genotypes of tomato inoculated with *M. incognita*. Biochemical analysis revealed higher total phenols, ortho dihydroxy phenols, flavanols, phenyl ammonia lyase and polyphenol oxidase activity in resistant genotypes than susceptible genotypes whereas catalase activity was recorded in the reverse trend. The resistant genotype Hisar Lal scored highest phenolic content 9.41g/100g followed by EC 520059 (9.2g/100g) and the lowest was seen in moderately susceptible genotype NF 31 (0.80g/100g).

Ravinderjit *et al.* (2013) investigated the influence of 28-homobrassinolide on activities of antioxidative enzymes *viz.* ascorbate peroxidise (APOX), guaiacol peroxidise (GPOX) and catalase of cowpea roots after *M.incognita* infestation. There was an increase in peroxidase activity in two cultivars of cowpea C152 (resistant) and Pusa Barsati (susceptible) inoculated with the nematode. Results

46

revealed that treatment with 28-homobrassinolide significantly increased the activities of all the three enzymes, suggesting the role of these plant steroids in enhancing the enzymatic levels, which have helped the host plant to better survive during pathogenesis and boosting the capacity of the plants to resist the damage caused by the parasite.

Studies conducted by Das *et al.* (2014) on the biochemical changes of nineteen new synthetic banana phase II hybrids revealed that total phenol content and activities of different enzymes such as peroxidase, phenyl ammonia lyase and polyphenol oxidase were higher in resistant plants than susceptible ones. The maximum per cent increase in PAL was recorded by H 531 (22.40 per cent), while the minimum by H-03-19 (7.04 per cent).The hybrid H 531 recorded the highest total phenol content of 419.48 μg/g in control and 491.23 μg/g under inoculated condition. The hybrid H 531 registered the highest peroxidase activity of 2.83 abs/min/g under control and 3.30 abs/min/g by H 531 under inoculated condition. Maximum polyphenol oxidase activity of 0.110 and 0.150 abs/min/g under control and inoculated conditions was reported in hybrid H 531.

A significant variation in total sugar and protein content was observed in *M.incognita* infested roots of bitter gourd than healthy plants. Total sugar was decreased at the rate by 33.64 per cent in the first week of infestation followed by 10.61 per cent in the second week and 0.03 per cent by fifth week. First week after infestation, maximum amount of protein was observed in infested roots than control. There was a tremendous increase of protein contents in infested roots at a rate of 105.26 per cent than control (Gautham and Podder, 2014).

Nayak (2015) observed the variation of total phenol content in three brinjal cultivars *i.e.* Pusa Purple Long (susceptible), Kantabaigan (resistant) and Pusa Kranti (resistant) infested with *M.incognita.* Both inoulated plants of resistant and susceptible cultivars contained maximum total phenol content than control plants. The total phenol content in healthy plants of susceptible variety was 0.687mg/g compared with resistant varieties (0.782 to 0.488 mg/g). After inoculation, percentage increase in phenol content of infested roots was 18.50, 27.90 and 42.90 in Kantabaigan, Pusa Purple Long and Pusa Kranti respectively.

Ranchana *et al*. (2015) conducted a study on biochemical constituents in the roots of ten tuberose genotypes to identify the genotype for hybridization which is resistant to *M. incognita*. The study revealed that among the genotypes, moderately resistant genotype Kahikuchi Single recorded with the highest level of phenol (19.84 mg g^{-1}) and increased activity of enzymes *viz.,* peroxidase (3.65 OD min^{-1} g^{-1}), poly phenol oxidase (3.58 OD mg g^{-1}), ortho-dihydroxy phenol (15.84 mg g^{-1}), acid phosphatase (131.88 m moles p-nitro phenol min^{-1} mg^{-1} protein) and phenylalanine ammonia lyase (16.10nmol of trans cinnamic acid min^{-1} g^{-1}) at 96 hours after inoculation.

Gupta (2016) estimated various metabolites *viz.,* aminoacids, chlorophyll and carbohydrates in the roots of *M.incognita* infested spinach. The results indicated that increased content of total carbohydrate 137.5 per cent had been recorded in the infested roots as compared to control plants. Total chlorophyll content was deteriorated in infested leaves (0.45 mg/g) as compared to 0.82 mg/g of control. Total free amino acid also increased in the infested roots than control.

48

Materials and methods

3. MATERIALS AND METHODS

The study entitled "Response of selected okra cultivars to root knot nematode *Meloidogyne incognita* (Kofoid and White, 1919)" was undertaken in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during January 2016 to October 2016 to screen the selected okra cultivars against root knot nematode and to elucidate the biochemical bases of resistance.

3.1. PREPARATION OF DENEMATIZED POTTING MIXTURE

Potting mixture was prepared by mixing sand, soil and well decomposed farm yard manure in the ratio 1:1:1 and denematised with three per cent formaldehyde @ 50 ml for 200 kg potting mixture. Formaldehyde solution was poured through the holes made on the heap of the potting mixture and the heap was tightly covered with polythene sheets. Polythene sheets were removed after one week and the potting mixture was raked well and covered for one more week. The polythene sheets were removed and the potting mixture was spread on the floor to remove the residues of formaldehyde. Samples were drawn randomly from the treated potting mixture to examine the presence of plant parasitic nematodes. This denematised potting mixture was used for conducting pot culture experiment.

3.2. MAINTENANCE OF PURE CULTURE OF ROOT KNOT NEMATODE

Rooted cuttings of coleus plants were used for the maintenance of root knot nematode culture. Coleus stem cuttings were planted in pots of size 25 cm diameter which were filled with denematised potting mixture. The egg masses obtained from the infested roots of okra were isolated and confirmed the species as *M. incognita* to get the pure culture of nematodes. The potted coleus plants were inoculated with one day old second stage juveniles of *M. incognita* emerged from the egg masses.

50

Repotting and inoculation was done periodically for multiplying root knot nematodes for the experiment.

3.3. POT CULTURE EXPERIMENT

Thirty cultivars/lines of okra were collected from Department of Olericulture, College of Horticulture, Vellanikkara, Department of Plant breeding & Genetics, College of Agriculture, Vellayani and NBPGR Regional Station, Thrissur were used for evaluating their resistance/tolerance to *Meloidogyne incognita*.

3.3.1. Raising potted plants

Polythene bags of size 16x35 cm were filled with denematised potting mixture for raising okra. Three to four presoaked seeds were sown per bag at a depth of 1-2 cm. One week after germination, thinning was done so as to maintain only one plant per bag. Regular watering and weeding was also done to keep the plants healthy and clean. Plants were maintained as per Package of Practices recommendation of Kerala Agricultural University (KAU, 2011).

3.3.2. Design and treatments

The experiment was laid out at in Completely Randomized Design with 30 treatments and three replications at College of Horticulture, Vellanikkara (Plate 2). The treatments were as follows.

Table 1. Details of okra cultivars evaluated

Treatments	Type of cultivar	Source
T_1 - IC 218900	Accession	ICAR- NBPGR Regional Station, Thrissur
T_2 - IC 112457	Accession	ICAR- NBPGR Regional Station, Thrissur
T_3 - IC 329360	Accession	ICAR- NBPGR Regional Station, Thrissur
T_4 - IC 111536	Accession	ICAR- NBPGR Regional Station, Thrissur
T_5 - IC 045819	Accession	ICAR- NBPGR Regional Station, Thrissur
T_6 - IC 111507	Accession	ICAR- NBPGR Regional Station, Thrissur
T_7 - Manjima	Hybrid	COA, Vellayani
T_8 - IC 117308	Accession	ICAR- NBPGR Regional Station, Thrissur
T_9 - IC 117228	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{10} - Anjitha	Variety	COA, Vellanyani
T_{11} - IC 117260	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{12} - Aruna	Variety	COH, Vellanikkara
T_{13} - Varsha Uphar	Variety	HISAR, Haryana
T_{14} - IC 117251	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{15} - IC 111525	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{16} - Kiran	Variety	COA, Vellayani

Contd... 52

T_{17} - IC 111500	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{18} - Susthira	Variety	COH, Vellanikkara
T_{19} - IC 111247	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{20} - IC 111514	Accession	ICAR- NBPGR Regional Station , Thrissur
T_{21} - IC 329357	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{22} - IC 117238	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{23} - Arka Anamika	Variety	ICAR- NBPGR Regional Station, Thrissur
T_{24} - IC 282275	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{25} - IC 469689	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{26} - IC 111517	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{27} - IC 305634	Accession	ICAR- NBPGR Regional Station, Thrissur
T_{28} - Pusa Sawani	Variety	ICAR- NBPGR Regional Station, Thrissur
T_{29} - Salkeerthi	Variety	ICAR- NBPGR Regional Station, Thrissur
T_{30} - IC 045515	Accession	ICAR- NBPGR Regional Station, Thrissur

Plate 1. Lay out of the experiment

3.3.3. Extraction of second stage juveniles of *M. incognita* for inoculation

Second stage juveniles of root knot nematode was extracted by Modified Baermann Funnel Technique (Schindler, 1961). Heavily infested plants from the culture pots were uprooted and washed with water to remove soil particles adhering to the roots. Then the egg masses from the galled roots were collected using forceps. Collected egg masses are kept over two layers of tissue paper supported on a wire mesh, which in turn was placed over petri dish containing water just enough to touch the egg masses. The juveniles hatched were settled at the bottom of the Petri dish (Plate 1). Sufficient number of Petri dishes were kept for getting the required number of second stage juveniles. Juveniles obtained from each Petri plate were collected in a beaker after every 12 h. This nematode suspension was used for inoculation.

3.3.4. Inoculation of second stage juveniles of *M.incognita* to okra plants

Population of the nematodes in the suspension was assessed after the extraction of nematodes. The nematode suspension collected in the beaker was made up to a constant volume by adding water. The nematode suspension was thoroughly mixed by blowing air with a pipette, an aliquot of 1 ml was pipetted out into a counting dish and the number of nematodes present was counted under a stereoscopic microscope. The process was repeated four times and average population per milliliter was estimated. The total population of nematodes present in the suspension was estimated by multiplying the average population per ml with total volume of nematode suspension. Each okra plant was inoculated with 100 ml suspension containing 7000 second stage juveniles of root knot nematodes after the plants had established *i.e.* two weeks after germination. The plants of each treatment without inoculation serve as the control of that treatment. At the time of inoculation, the suspension was thoroughly mixed by blowing air with a pipette to get uniform distribution of nematodes. The suspension was then poured into the root zone of the plants, by making holes of about 5 cm depth on all sides of the plant using a glass

55

Plate 2. Extraction of second stage juveniles of *M. incognita* for inoculation

M. incognita infested root

Egg masses of *M. incognita* on root galls

Egg mass picking from *M. incognita* infested root

Extraction of second stage juveniles of *M. incognita* rod. After pouring the entire suspension, the holes were covered with thin layer of soil.

3.4. BIOCHEMICAL STUDIES

Biochemical basis of resistance of okra cultivars to root knot nematode were estimated by analyzing the activity of peroxidase (PO), total phenol, total sugar and reducing sugar content after three months of inoculation of *M. incognita*. To evaluate these parameters, root samples were randomly collected from each plant. Roots were washed thoroughly to remove the adhering debris and soil particles. Excess water was removed using a tissue paper and roots were kept in a labeled polythene cover. The root samples were transported from field to lab in an ice box to maintain low temperature and this temperature was maintained until the end of the experiment.

3.4.1. Total phenol content

Total phenol was estimated with the folin-ciocalteau reagent using method described by Malik and Singh (1980).

The homogenate was prepared by grinding 0.5 g fresh okra roots with 10 ml of 80 percent ethanol. This homogenate was centrifuged at 10,000 rpm for 20 minutes and the supernatant was collected in a test tube and kept in a hot water bath to evaporate the ethanol. The pellets thus obtained were dissolved in five milliliter distilled water. Folin-ciocalteau reagent (0.5ml) was added into a test tube containing 0.2 ml of sample solution and 2.8 ml of distilled water and then heated for three minutes. Two milliliter of 20 per cent Na_2CO_3 solution was added to the test tube and the absorbance was measured at 650 nm using spectrophotometer (Model-4001/4 Thermo Spectronic, Thermo Electronic Corporation, USA). The concentration of phenols in the sample was estimated by using a standard solution of catechol and total phenol was expressed as mg g^{-1} of fresh weight. Calculation was carried out by the formula, given below.

Total phenol content in units/g of the sample =

$$\frac{\text{Test sample absorbance}}{\text{Standard solution absorbance}} \times \frac{\text{Concentration of standard solution}}{\text{Weight of sample}}$$

3.4.2. Peroxidase (PO) activity

The peroxidase activity of okra roots were analyzed as per the procedure described by Malik and Singh (1980).

The enzyme was extracted by grinding one gram fresh okra roots of each variety in three ml of 0.1M phosphate buffer with pH 7 in a pre-cooled mortar and pestle. The homogenate obtained was centrifuged at 10,000 rpm at 5° C for 15 minutes and the supernatant was used as enzyme source. Three milliliters of 0.1 M phosphate buffer solution, 0.05 ml of 20 mM guaiacol solution, 0.1ml enzyme extract and 0.03 ml of 12.3 mM hydrogen peroxide solution were pipetted out into a cuvette and mixed well. Readings were taken at 436 nm in spectrophotometer (Model-4001/4 Thermo Spectronic, Thermo Electronic Corporation, USA) such that the absorbance was increased by 0.05. The time required in minutes (Δt) for increase in the absorbance by 0.1 was noted with the help of a stop watch.

$$\text{Enzyme activity units/gram} = \frac{3.18 \times 0.1}{6.39 \times \Delta t \times 0.1} = \frac{500}{\Delta t}$$

3.4.3. Total sugar

Total sugar content was estimated as per the procedure by Hedge and Hofreiter (1962).

Weighed 100 mg of the sample into a boiling tube. Hydrolyzed by keeping it in a boiling water bath for three hours with 5ml of 2.5 N HCl and cooled to room temperature. Neutralized it with solid sodium carbonate until the effervescence ceases. Made up the volume to 100 ml and centrifuged. Collected the supernatant and

58

took 0.5 ml aliquots for analysis. Prepared the standards by taking 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard. '0' serves as blank. Made up the volume to 1ml in all the tubes including the sample tubes by adding distilled water. Then added 4ml of anthrone reagent. Heated for eight minutes in a boiling water bath. Cooled rapidly and read the green to dark green colour at 630 nm. Drew a standard graph by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. From the graph calculate the amount of carbohydrate present in the sample tube.

Amount of total sugar present in units/g of the sample =

$$\frac{\text{Test sample absorbance x } 0.1 \text{ x } 100}{\text{Volume of test sample x weight of sample}}$$

3.4.4. Reducing sugar

Reducing sugar content in okra roots was analyzed as per the procedure by Somogyi (1952).

Weighed 100 mg of the sample and extracted the sugars with hot 80% ethanol twice (5 ml each time). Collected the supernatant and evaporate it by keeping it on a water bath at 80°C. Added 10 ml water and dissolve the sugars. Pipetted out aliquots of 0.1 ml to separate test tubes. Pipetted out 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard solution into a series of test tubes. Made up the volume in both sample and standard tubes to 2 ml with distilled water. Pipetted out 2 ml distilled water in a separate tube to set a blank. Added 1 ml of alkaline copper tartrate reagent to each tube. Tubes were placed in boiling water for 10 minutes. Cooled the tubes and add 1 ml of arsenomolybdic acid reagent to all the tubes. Made up the volume in each tube to 10 ml with water. Read the absorbance of blue colour at 620 nm after 10 min. From the graph drawn, calculated the amount of reducing sugars present in the sample.

Amount of reducing sugar present in units/g of the sample =

$$\frac{\text{Test sample absorbance x 0.1 x 10}}{\text{Volume of test sample x weight of sample}}$$

3.5. OBSERVATIONS

Okra plants were allowed to grow for a period of three months after inoculation. The following biometric characters were recorded at fortnightly intervals:

a) Height of the plant
b) Number of leaves
c) Number of flowers
d) Number of fruits
e) Fruit weight
f) Shoot weight
g) Root weight

Three months after inoculation, the plants were uprooted and the following observations were taken

a) Nematode population in 200 g soil
b) Nematode population in 10 g roots
c) Number of root knots in 10 g roots
d) Root knot index

3.5.1 Estimation of nematode population from soil

Three months after inoculation the plants were uprooted and the population of nematodes in the soil was estimated. A composite sample of 200g soil was collected from the root zone of each okra plant grown in polythene bag and processed for extracting the nematodes. Cobb's decanting and sieving technique (Cobb, 1918) was followed to extract the nematodes from soil samples from different treatments. The residue obtained from 100, 200 and 325 mesh sieves were collected in a 250 ml beaker. The residue thus collected was cleared by Modified Baermann Funnel technique (Schindler, 1961). The nematode population was estimated with the help of a stereoscopic microscope.

3.5.2. Estimation of root knots from 10g root

Okra plants were carefully lifted by removing the polythene bag and the loose soil. Collected roots were carefully washed with water to remove adhering soil particles. Ten gram roots was randomly taken and pressed gently between the folds of blotting paper to remove excess water. The number of galls in10g of root sample was recorded.

3.5.3. Root knot index

Based on the number of galls counted, the root knot index was assessed by rating on a 1-5 scale and the cultivars were categorized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible (Devi *et al.* 2014).

Table 2. Classification of resistance based on root knot index and number of root knots

Sl. No.	Root knot index	No. of galls/ plant	Reaction
1	1	No gall	Highly resistant
2	2	1-10 galls	Resistant
3	3	11-30 galls	Moderately resistant
4	4	31-100 galls	Susceptible
5	5	101 and above	Highly susceptible

61

3.5.4. Estimation of nematode population from root

Root samples used for counting the number of galls were used for extracting the second stage juveniles using Modified Baermann Funnel technique (Schindler, 1961). The root samples were cut in to small pieces and placed over two layers of tissue paper supported on a wire mesh which in turn was placed over a Petri dish. The nematode suspension in the Petri plate was collected in a beaker during every 12 h. This was continued till no nematode was obtained.The nematode suspension thus obtained was pooled together and the population of nematodes was assessed under a stereoscopic microscope.

3.6. STATISTICAL ANALYSIS

Data collected from the study were analyzed by statistical method for CRD and ANOVA. Analysis of variance was done using statistical software 'OPSTAT'. The treatments are compared using Least Significant Difference (LSD) values. Pearsons correlation test was done using the statistical package, SPSS (Statistical Package for Social Sciences) to compare the different parameters.

Results

4. RESULTS

The results of the study entitled "Response of selected okra [*Abelmoschus esculentus* (L.) Moench] cultivars to root knot nematode, *Meloidogyne incognita* (Kofoid and White)" conducted at College of Horticulture, Vellanikkara is presented in this chapter.

4.1. SCREENING OF OKRA CULTIVARS AGAINST ROOT KNOT NEMATODE

Thirty cultivars of okra were screened for resistance to *M. incognita* (Kofoid and White). Seeds of okra were sown in poly bags filled with denematised potting mixture. Two weeks after germination, the plants were inoculated with second stage juveniles (J_2) of *M. incognita* @ one J_2 per gram of soil. Three months after inoculation all the plants were uprooted. The results are presented below.

4.1.1. Biometric characters of okra

The biometric characters *viz.,* plant height, number of leaves, number of flowers, number of fruits, fruit weight, shoot weight and root weight of thirty okra cultivars were observed at fortnightly intervals from the time of inoculation till uprooting (three months after inoculation). The per cent reduction in the growth parameters were calculated over control as follows,

$$\text{Per cent reduction} = \frac{\text{Control} - \text{inoculated}}{\text{Control}} \times 100$$

4.1.1.1. Height of the plant

The height of the okra plants at the time of inoculation and per cent decrease in height over control are presented in Table 3. The results indicated that all the cultivars showed decreasing trend in terms of height with respect to the control and

64

significant variation existed among the cultivars. At the time of inoculation, maximum plant height was recorded in cultivar Arka Anamika (13.58 cm) and this was statistically on par with cultivars Pusa Sawani (13.33 cm), IC 117308 (13.25 cm), Aruna (13.23 cm), Varsha Uphar (13.18 cm) and IC 111507 (13.16 cm). However there was no significant variation in plant height at first fortnight after inoculation. On second fortnight onwards, minimum reduction in plant height was recorded in cultivar IC 117238 (0.73 per cent) (Plate 4) followed by Varsha Uphar (1.04 per cent), IC 117251 (1.47 per cent) and IC 111507 (1.58 per cent). These were statistically on par with each other. This trend in minimum reduction of height was recorded in IC 117238 (4.78, 5.39, 6.29 and 8.02 per cent) at 3rd, 4th, 5th and 6th fortnight after inoculation (Plate 4) and this was statistically on par with Varsha Uphar (3.92, 6.66, 7.75 and 9.31 per cent) and IC 117251 (4.84, 6.65, 8.34 and 13.67 per cent). At the time of uprooting maximum reduction in height was recorded in cultivar Susthira (46.85 per cent) (Plate 3) followed by IC 117228 (42.77 per cent) and Arka Anamika (41.32 per cent) respectively.

4.1.1.2. Number of leaves

Statistical analysis of the data indicated that there was significant variation in the number of leaves of different cultivars (Table 4). At the time of inoculation, the number of leaves ranged from 4.00 to 5.75. At second fortnight after inoculation cultivar Susthira recorded maximum per cent decrease in leaf number with 23.66 per cent (Plate 3), which was significantly different from other cultivars. At the time of uprooting, the maximum decrease in number of leaves was in the same cultivar Susthira (70.25 per cent), which was statistically on par with Arka Anamika (66.84 per cent). The minimum per cent decrease in number of leaves was observed in cultivar IC 117238 (18.87 per cent) (Plate 4), which was statistically on par with IC 117251 (21.91 per cent) and these are significantly different from other cultivars.

Plate 3. Influence of *Meloidogyne incognita* infestation on cultivar Susthira (highly susceptible)

Control plant

Inoculated plant

Plate 4. Influence of *Meloidogyne incognita* infestation on cultivar IC 117238 (moderately resistant)

Control plant

Inoculated plant

4.1.1.3. Number of flowers

The total number of flowers produced from the second fortnight after inoculation to the time of uprooting varied significantly in the okra cultivars evaluated. Reduction in number of flowers was observed in all the cultivars (Table 5). There was no significant difference in flower numbers during 2nd and 3rd fortnight after inoculation. On 4th fortnight onwards the minimum reduction in flowering was observed in cultivar IC 117238. The trend in minimum reduction of flower number was recorded in IC 117238 (3.06, 6.48 and 16.89 per cent) at 4th, 5th and 6th fortnight after inoculation and this was followed by Varsha Uphar (4.28, 7.61 and 18.81 per cent). At the time of uprooting cultivar Susthira recorded maximum reduction in number of flowers with 48.12 per cent followed by Pusa Sawani and Salkeerthi with 48.06 per cent and 46.70 per cent.

4.1.1.4. Number of fruits

Statistical analysis of the data indicated that there was significant variation in number of fruits with respect to different cultivars (Table 6). Cultivar IC 117238 recorded minimum reduction with 5.99 per cent at 4th fortnight after inoculation and this was statistically on par with cultivar IC 111507 with 6.58 per cent. At the time of uprooting the minimum reduction was observed in IC 117238 with 18.33 per cent followed by IC 111507 and Varsha Uphar with 19.00 and 19.48 per cent respectively. Cultivar Susthira recorded maximum reduction in fruit production with 49.76 per cent followed by Arka Anamika with 49.75 and these were statistically on par with each other.

4.1.1.5. Fruit weight

The observations on fruit weight of the okra cultivars are presented in Table 7. The results indicated that all the cultivars showed a decreasing trend in terms of fruit weight due to nematode infestation and significant variation existed among the

68

Plate 5. Influence of *Meloidogyne incognita* infestation on fruit weight of okra cultivars

IC 117238 (moderately resistant)

IC 117251(moderately resistant)

IC 111536 (susceptible)

IC 305634 (highly susceptible)

cultivars. However there was no significant variation in fruit weight during 2nd and 3rd fortnight after inoculation. From 4th fortnight onwards, the maximum reduction in fruit weight was observed in cultivar IC 111536 with 3.47, 7.05 and 11.16 per cent, which was statistically on par with IC 305634 with 3.18, 7.36 and 10.25 per cent. The minimum reduction in fruit weight was observed in IC 117238 (0.52, 1.15 and 1.70 per cent) from 4th fortnight after inoculation upto the time of uprooting (Plate 5).

4.1.1.6. Shoot weight

Statistical analysis of shoot weight of different cultivars is given in the Table 8. All the cultivars showed significant reduction in shoot weight than the control plants due to nematode infestation. Cultivar Susthira recorded maximum reduction in shoot weight with 72.08 per cent followed by Aruna (69.40 per cent), IC 329360 (65.16 per cent) and Arka Anamika (62.66 per cent). Minimum reduction in shoot weight was recorded in Anjitha with 24.23 per cent, which was statistically on par with IC 117238 (25.68 per cent) followed by Varsha Uphar (27.41 per cent) and IC 111507 (27.72 per cent). Decrease in shoot weight of rest of the cultivars ranged from 29.89 to 60.34 per cent.

4.1.1.7. Root weight

Root weight of different cultivars at the time of uprooting is given in Table 9. All the cultivars showed significant reduction in root weight than the control plants. Decrease in root weight of different cultivars ranged from 3.15 per cent to 36.56 per cent. Cultivar IC 117251 recorded minimum decrease with 3.15 per cent and this is statistically on par with IC 111507 (3.53 per cent) followed by IC 117238 (3.61 per cent), Kiran (5.93 per cent), IC 469689 (6.56 per cent) and Varsha Uphar (6.64 per cent). Maximum decrease in root weight was observed in Arka Anamika with 36.56 per cent followed by IC 117308 and Salkeerthi with 36.47 and 35.02 per cent respectively.

Table 3. Influence of *Meloidogyne incognita* infestation on plant height of okra cultivars

Treatments	Plant height at the time of inoculation	Per cent decrease in height of the plants					
		Fortnightly interval after inoculation					
		1	2	3	4	5	6
T_1 - IC 218900	12.40	1.14	4.24	16.18	27.76	31.15	36.55
T_2 - IC 112457	11.58	0.78	6.25	18.13	28.03	31.13	34.37
T_3 - IC 329360	12.05	1.24	5.87	16.66	26.91	31.70	36.18
T_4 - IC 111536	9.58	0.95	3.54	13.57	25.55	30.31	40.53
T_5 - IC 045819	12.08	1.48	7.41	16.74	24.36	31.76	38.90
T_6 - IC 111507	13.16	0.81	1.58	4.73	7.68	13.01	17.73
T_7 - Manjima	9.80	0.91	5.18	13.7	31.43	35.90	38.80
T_8 - IC 117308	13.25	0.86	3.61	11.54	21.38	31.10	40.95
T_9 - IC 117228	12.43	1.18	8.02	14.67	28.64	31.34	42.77
T_{10} - Anjitha	10.55	0.79	3.72	15.68	20.79	25.20	34.92
T_{11} - IC 117260	12.63	0.59	4.11	9.34	10.89	12.20	28.92
T_{12} - Aruna	13.23	0.50	9.26	8.83	12.05	18.73	40.81
T_{13} - Varsha Uphar	13.18	0.71	1.04	3.92	6.66	7.75	9.31
T_{14} - IC 117251	11.23	1.6	1.47	4.84	6.65	8.34	13.67
T_{15} - IC 111525	10.23	1.02	4.81	9.00	11.54	15.38	20.80

Contd…

Treatments	Plant height at the time of inoculation	Per cent decrease in height of the plants					
		Fortnightly interval after inoculation					
		1	**2**	**3**	**4**	**5**	**6**
T_{16} - Kiran	10.45	1.26	4.71	17.61	14.43	18.00	26.21
T_{17} - IC 111500	11.53	1.20	4.16	11.09	19.07	22.84	30.70
T_{18} - Susthira	9.70	0.64	3.25	20.23	26.30	30.63	46.85
T_{19} - IC 111247	11.73	1.53	2.18	11.67	22.51	25.29	32.60
T_{20} - IC 111514	10.68	1.86	3.56	11.40	24.01	26.45	33.74
T_{21} - IC 329357	10.70	0.42	4.98	13.15	26.01	29.77	39.62
T_{22} - IC 117238	10.13	0.41	0.73	4.78	5.39	6.29	8.02
T_{23} - Arka Anamika	13.58	1.03	5.40	19.56	27.25	31.47	41.32
T_{24} - IC 282275	11.28	1.28	8.29	13.57	25.18	28.76	34.09
T_{25} - IC 469689	10.45	1.00	3.29	10.53	25.29	28.08	37.44
T_{26} - IC111517	11.50	0.89	3.72	12.58	18.89	19.19	25.26
T_{27} - IC 305634	12.40	0.95	3.43	14.73	26.06	31.87	38.04
T_{28} - Pusa Sawani	13.33	0.82	4.31	9.34	20.26	31.85	39.55
T_{29} - Salkeerthi	11.53	1.10	3.74	13.88	24.89	29.48	35.83
T_{30} - IC 045515	12.60	2.40	8.33	15.13	19.07	25.04	32.96
CD Value (0.05 level)	0.45	NS	1.24	2.53	3.98	5.32	9.32

*Values are mean of three replications

72

Table 4. Influence of *Meloidogyne incognita* infestation on number of leaves of okra cultivars

Treatments	Number of leaves at the time of inoculation	Per cent decrease in number of leaves					
		Fortnightly interval after inoculation					
		1	2	3	4	5	6
T_1 - IC 218900	4.00	1.48	3.85	13.26	21.45	32.04	40.06
T_2 - IC 112457	4.25	2.91	4.94	16.05	24.24	30.70	36.74
T_3 - IC 329360	4.50	4.84	8.54	18.95	26.25	29.30	31.60
T_4 - IC 111536	4.00	6.40	12.92	19.35	30.66	33.95	44.28
T_5 - IC 045819	4.75	3.61	7.41	14.24	22.20	39.10	46.19
T_6 - IC 111507	4.75	2.26	3.56	7.89	10.54	19.04	27.78
T_7 - Manjima	4.50	5.36	8.95	17.17	24.74	28.66	37.15
T_8 - IC 117308	5.00	1.66	7.41	13.59	21.13	38.35	45.09
T_9 - IC 117228	4.75	4.40	8.95	17.55	24.59	35.30	40.66
T_{10} - Anjitha	4.50	2.81	6.04	12.34	20.67	34.11	38.27
T_{11} - IC 117260	4.50	3.16	8.60	16.32	20.26	24.65	40.13
T_{12} - Aruna	5.00	4.14	12.94	20.48	26.57	32.69	41.50
T_{13} - Varsha Uphar	5.75	0.28	2.79	6.52	11.89	22.55	27.23
T_{14} - IC 117251	5.25	0.85	3.88	7.70	13.47	16.00	21.91
T_{15} - IC 111525	4.50	3.96	6.04	9.31	14.51	19.80	29.43
T_{16} - Kiran	4.75	1.77	4.99	8.88	10.26	25.36	29.37

(Contd…..)

Treatments	Number of leaves at the time of inoculation	Per cent decrease in number of leaves					
		Fortnightly interval after inoculation					
		1	2	3	4	5	6
T_{17} - IC 111500	5.25	1.69	4.76	9.31	11.20	27.27	34.94
T_{18} - Susthira	4.75	14.45	23.66	31.09	41.95	46.29	70.25
T_{19} - IC 111247	5.25	6.00	7.41	11.65	14.46	22.22	33.19
T_{20} - IC 111514	5.50	9.57	16.63	28.69	32.31	27.04	30.90
T_{21} - IC 329357	5.25	3.51	10.34	22.15	27.67	38.70	46.69
T_{22} - IC 117238	3.25	0.78	2.42	6.18	7.70	18.13	18.87
T_{23} - Arka Anamika	5.00	7.35	15.15	25.82	39.86	45.35	66.84
T_{24} - IC 282275	5.00	3.35	6.98	11.60	16.35	27.51	39.92
T_{25} - IC 469689	5.00	5.50	8.88	14.98	22.12	36.35	51.91
T_{26} - IC111517	4.75	1.81	6.04	14.68	22.15	36.70	49.02
T_{27} - IC 305634	5.25	4.31	8.15	10.40	18.40	33.49	39.14
T_{28} - Pusa Sawani	4.50	2.20	10.94	18.28	25.45	42.49	46.69
T_{29} - Salkeerthi	4.00	6.19	17.01	23.58	30.15	35.95	45.56
T_{30} - IC 045515	4.50	5.66	9.44	11.64	17.90	19.90	36.93
CD Value (0.05 level)	0.21	NS	1.19	2.22	2.53	3.41	4.45

*Values are mean of three replications

74

Table 5. Influence of *Meloidogyne incognita* infestation on number of flowers of okra cultivars

Treatments	Per cent reduction in flower number (Mean of three replications)				
	Fortnightly interval after inoculation				
	2	**3**	**4**	**5**	**6**
T_1 - IC 218900	1.63	5.76	22.92	30.08	46.33
T_2 - IC 112457	0.00	8.02	23.77	27.62	37.21
T_3 - IC 329360	1.75	10.43	26.00	29.16	41.27
T_4 - IC 111536	1.52	5.13	13.81	21.38	29.42
T_5 - IC 045819	6.11	13.23	30.65	30.10	43.97
T_6 - IC 111507	0.00	2.51	4.46	10.97	19.75
T_7 - Manjima	3.20	11.84	12.98	22.37	24.67
T_8 - IC 117308	0.00	6.00	12.41	18.70	40.42
T_9 - IC 117228	1.50	8.72	24.03	20.97	43.30
T_{10} - Anjitha	5.84	9.44	15.92	24.41	40.57
T_{11} - IC 117260	0.00	7.19	13.27	18.36	25.20
T_{12} - Aruna	5.36	11.16	23.35	28.06	42.19
T_{13} - Varsha Uphar	0.00	0.00	4.28	7.61	18.81
T_{14} - IC 117251	3.70	7.21	9.91	17.43	19.02
T_{15} - IC 111525	0.83	12.12	19.16	24.09	37.69

(Contd ...)

Treatments	Per cent reduction in flower number (Mean of three replications) Fortnightly interval after inoculation				
	2	**3**	**4**	**5**	**6**
T_{16} - Kiran	1.97	17.84	26.54	25.14	32.32
T_{17} - IC 111500	0.83	17.06	19.56	19.55	21.24
T_{18} - Susthira	0.00	17.23	35.47	38.36	48.12
T_{19} - IC 111247	3.60	14.10	17.47	20.11	26.95
T_{20} - IC 111514	2.88	10.26	21.62	25.64	32.70
T_{21} - IC329357	1.35	8.73	17.74	26.74	33.40
T_{22} - IC 117238	0.00	0.65	3.06	6.48	16.89
T_{23} - Arka Anamika	4.30	16.67	28.72	30.69	45.19
T_{24} - IC282275	3.03	16.40	16.30	26.15	31.14
T_{25} - IC 469689	4.46	5.13	11.11	19.59	23.22
T_{26} - IC111517	3.03	6.45	19.56	20.13	23.33
T_{27} - IC 305634	0.83	7.41	25.32	29.32	39.61
T_{28} - Pusa Sawani	4.26	12.35	35.04	37.20	48.06
T_{29} - Salkeerthi	4.76	13.38	34.46	36.84	46.70
T_{30} - IC 045515	5.08	16.77	27.78	29.72	44.71
CD Value (0.05 level)	NS	NS	1.16	1.82	2.1

Flowering of okra plants not initiated at first fortnightly interval after inoculation

76

Table 6. Influence of *Meloidogyne incognita* infestation on number of fruits of okra cultivars

Treatments	Per cent reduction in number of fruits (Mean of three replications)				
	Fortnightly interval after inoculation				
	2	**3**	**4**	**5**	**6**
T_1 - IC 218900	1.63	6.02	25.09	41.07	46.60
T_2 - IC 112457	0.00	7.14	32.23	35.90	40.26
T_3 - IC 329360	1.50	9.01	26.59	34.63	44.57
T_4 - IC 111536	1.69	16.55	34.50	42.67	46.90
T_5 - IC 045819	5.66	13.70	34.44	40.12	43.45
T_6 - IC 111507	0.00	0.00	6.58	14.16	19.00
T_7 - Manjima	3.20	12.74	15.87	24.21	29.86
T_8 - IC 117308	0.00	5.26	30.45	37.69	42.83
T_9 - IC 117228	2.38	7.14	29.18	42.92	36.51
T_{10} - Anjitha	1.96	3.18	28.26	34.33	41.75
T_{11} - IC 117260	0.00	7.44	18.33	30.03	38.84
T_{12} - Aruna	5.36	14.16	27.33	37.56	46.15
T_{13} - Varsha Uphar	0.00	0.00	7.89	12.73	19.48
T_{14} - IC 117251	0.00	3.76	10.53	19.88	25.71
T_{15} - IC 111525	1.75	13.79	28.26	33.45	41.75

(Contd…..)

Treatments	Per cent reduction in number of fruits (Mean of three replications)				
	Fortnightly interval after inoculation				
	2	3	4	5	6
T_{16} - Kiran	2.76	17.84	24.00	33.58	34.25
T_{17} - IC 111500	0.83	17.91	20.97	24.89	38.00
T_{18} - Susthira	0.00	16.67	36.53	44.33	49.76
T_{19} - IC 111247	2.27	14.10	16.67	28.33	36.58
T_{20} - IC 111514	2.50	11.76	29.24	40.65	44.75
T_{21} - IC 329357	3.85	7.49	30.18	36.73	44.39
T_{22} - IC 117238	0.00	0.00	5.99	11.00	18.33
T_{23} - Arka Anamika	1.79	16.82	35.38	44.23	49.75
T_{24} - IC 282275	3.10	19.58	33.05	39.31	45.08
T_{25} - IC 469689	2.70	5.48	14.67	19.00	33.33
T_{26} - IC 111517	3.25	6.02	17.41	28.33	33.71
T_{27} - IC 305634	0.00	4.80	33.88	36.33	39.32
T_{28} - Pusa Sawani	3.25	5.13	19.48	22.33	37.30
T_{29} - Salkeerthi	4.76	18.55	32.73	39.82	44.64
T_{30} - IC 045515	5.50	16.72	31.21	36.59	45.50
CD Value (0.05 level)	NS	NS	1.25	1.42	1.79

Fruiting of okra plants not initiated at first fortnightly interval after inoculation

Table 7. Influence of *Meloidogyne incognita* infestation on fruit weight of okra cultivars

Treatments	Per cent reduction in fruit weight (Mean of three replications) Fortnightly interval after inoculation				
	2	3	4	5	6
T_1 - IC 218900	0.71	1.03	2.72	5.04	7.25
T_2 - IC 112457	0.72	1.73	2.04	4.92	5.20
T_3 - IC 329360	1.32	1.03	1.84	3.08	5.60
T_4 - IC 111536	1.59	2.42	3.47	7.05	11.16
T_5 - IC 045819	0.62	1.69	2.94	5.34	7.38
T_6 - IC 111507	0.41	0.75	1.23	1.63	2.78
T_7 - Manjima	0.27	1.69	1.24	3.07	5.42
T_8 - IC 117308	0.84	1.28	1.42	3.22	4.43
T_9 - IC 117228	1.15	1.03	1.38	1.46	3.63
T_{10} - Anjitha	1.09	1.26	2.26	4.09	5.75
T_{11} - IC 117260	0.49	1.41	1.73	5.46	3.35
T_{12} - Aruna	1.03	1.60	2.19	3.13	5.12
T_{13} - Varsha Uphar	0.21	0.82	1.22	1.35	1.98
T_{14} - IC 117251	0.22	1.31	0.79	1.20	1.90
T_{15} - IC 111525	1.46	1.78	2.09	1.89	3.03

(Contd....)

Treatments	Per cent reduction in fruit weight (Mean of three replications)				
	Fortnightly interval after inoculation				
	2	**3**	**4**	**5**	**6**
T_{16} - Kiran	0.49	0.61	1.57	3.00	5.01
T_{17} - IC 111500	0.59	1.23	1.55	2.21	3.12
T_{18} - Susthira	0.00	1.03	3.15	6.02	8.33
T_{19} - IC 111247	0.91	1.81	2.96	3.75	4.36
T_{20} - IC 111514	0.95	1.72	2.19	2.38	3.96
T_{21} - IC 329357	0.20	0.87	2.48	4.53	6.03
T_{22} - IC 117238	0.51	0.46	0.52	1.15	1.70
T_{23} - Arka Anamika	1.03	1.47	2.39	6.28	8.28
T_{24} - IC 282275	1.21	1.33	3.03	6.06	8.50
T_{25} - IC 469689	1.15	1.15	2.46	5.63	6.20
T_{26} - IC 111517	0.90	1.56	2.91	5.54	7.69
T_{27} - IC 305634	1.51	2.08	3.18	7.36	10.25
T_{28} - Pusa Sawani	0.65	1.16	2.25	4.26	5.81
T_{29} - Salkeerthi	0.68	1.04	1.54	3.53	4.84
T_{30} - IC 045515	0.65	1.48	1.79	3.49	4.58
CD Value (0.05 level)	NS	NS	0.38	0.61	1.13

Fruiting of okra plants not initiated at first fortnightly interval after inoculation

80

Table 8. Influence of *Meloidogyne incognita* infestation on shoot weight and root weight of okra cultivars

Treatments	Shoot weight (Mean of three replication)			Root weight (Mean of three replication)		
	Inoculated (g)	Control (g)	Per cent decrease over control	Inoculated (g)	Control (g)	Per cent decrease over control
T_1 - IC 218900	41.93	100.20	58.15	27.00	35.01	22.88
T_2 - IC 112457	66.10	149.00	55.64	19.47	22.31	12.73
T_3 - IC 329360	42.33	121.50	65.16	28.37	32.02	11.40
T_4 - IC 111536	53.37	85.21	37.37	26.47	29.52	10.33
T_5 - IC 045819	41.97	80.21	47.67	25.00	28.93	13.58
T_6 - IC 111507	64.33	89.00	27.72	27.63	28.64	3.53
T_7 - Manjima	49.53	99.86	50.40	18.50	26.81	31.00
T_8 - IC 117308	51.60	96.51	46.53	20.03	31.53	36.47
T_9 - IC 117228	49.77	98.50	49.47	19.33	26.71	27.63
T_{10} - Anjitha	58.73	77.51	24.23	25.80	30.53	15.49
T_{11} - IC 117260	44.33	87.50	49.34	27.63	35.20	21.51
T_{12} - Aruna	37.33	122.00	69.40	29.60	40.52	26.95
T_{13} - Varsha Uphar	68.83	94.82	27.41	21.67	23.21	6.64
T_{14} - IC 117251	65.00	92.71	29.89	28.60	29.53	3.15
T_{15} - IC 111525	49.33	89.51	44.89	28.77	33.53	14.20

(Contd…)

8

Treatments	Shoot weight (Mean of three replication)			Root weight (Mean of three replication)		
	Inoculated (g)	Control (g)	Per cent decrease over control	Inoculated (g)	Control (g)	Per cent decrease over control
T_{16} - Kiran	52.77	80.22	34.22	25.87	27.50	5.93
T_{17} - IC 111500	56.47	95.63	40.95	14.70	16.06	8.47
T_{18} - Susthira	46.07	165.00	72.08	29.73	40.85	27.22
T_{19} - IC 111247	39.77	86.52	54.03	25.47	30.22	15.72
T_{20} - IC 111514	40.77	93.81	56.54	21.73	24.23	10.32
T_{21} - IC 329357	37.60	94.81	60.34	14.10	20.53	31.32
T_{22} - IC 117238	59.63	80.23	25.68	27.47	28.50	3.61
T_{23} - Arka Anamika	38.17	102.21	62.66	22.56	35.56	36.56
T_{24} - IC 282275	65.57	95.82	31.57	23.53	25.62	8.16
T_{25} - IC 469689	62.67	102.54	38.88	16.37	17.52	6.56
T_{26} - IC 111517	66.77	121.52	45.05	13.53	16.44	17.70
T_{27} - IC 305634	59.47	90.66	34.40	17.60	21.20	16.98
T_{28} - Pusa Sawani	63.17	125.44	49.64	28.70	42.22	32.02
T_{29} - Salkeerthi	66.53	110.23	39.64	16.77	25.80	35.00
T_{30} - IC 045515	54.63	95.51	42.80	27.07	31.50	14.06
CD Value (0.05 level)	2.45	4.53	2.32	0.60	0.82	2.07

4.1.2. Nematode population

Thirty okra cultivars were screened for the evaluation of resistance/susceptibility reaction against *M. incognita*. Population of nematodes in soil and root, number of root knots formed due to the nematode infestation and root knot index were considered for rating the cultivars as resistant or susceptible.

4.1.2.1. Nematode population in soil

Nematode population in soil collected from root zone of all the okra cultivars at the time of uprooting is presented in Table 9. Data showed significant variation among the different cultivars. The mean nematode population in soil ranged from 31.66 to 135.30 per 200 g soil. The highest population was obtained from the cultivar Susthira with 135.30 per 200 g soil followed by IC 218900, Pusa Sawani and Aruna with an average nematode population of 130.66, 125.33 and 124.66 per 200 g soil respectively. The lowest population of nematodes was recorded from Varsha Uphar (31.66/200 g soil) followed by IC 117238 and IC 117251 with an average population of 34.33 and 36.12 per 200 g soil respectively, which were statistically on par. Nematode population from rest of the varieties varied between 41.00 and 109.66 per 200 g soil.

4.1.2.2. Nematode population in root

Statistical analysis of the data indicated that there was significant variation in the nematode population among the different cultivars (Table 9). Highest population was recorded from IC 218900 with an average of 486.00 per 10 g root followed by Susthira (485.33), Aruna (480.33) and IC 329360 (478.33). These were statistically on par. The lowest nematode population was recorded from IC 117238 with 55.00 per 10 g root followed by IC 117251 (62.67 per 10 g root) and Varsha Uphar (76.67 per 10 g root). Nematode population in all other varieties varied between 79.00 to 467.33 per 10 g root. 83

4.1.2.3. Number of root knots

The number of root knots in 10g roots is presented in Table 9.The number of root knots among the different cultivars varied between 19.66 (IC 117238) and 266.00 (Susthira). IC 117238 was found to be statistically on par with IC 111507 (22.66) followed by Varsha Uphar (24.20). IC 218900 (261.32) was found to be statistically on par with Susthira. All other cultivars were reported to have root knots in between 28.33 and 220.66.

4.1.2.4. Root knot index

Data regarding root knot index are presented in Table 9. Considering the root knot index the superior cultivars were IC 117238, IC 117251, IC 111507 and Varsha Uphar with a root knot index of 3. The cultivars *viz.,* IC 111536, Manjima, IC 117260, IC 111500, IC 111247, IC 469689 and IC 111517 were having a root knot index of 4. The highest root knot index of 5 was scored by IC 218900, IC 112457, IC 329360, IC 045819, IC 117308, IC 117228, Anjitha, Aruna, IC 111525, Kiran, Susthira, IC 111514, IC 329357, Arka Anamika, IC 282275, IC 305634, IC 045515, Pusa Sawani and Salkeerthi.

Based on root knot number and root knot index four cultivars *viz.,* IC 117238, IC 117251, IC 111507 and Varsha Uphar can be rated as moderately resistant to *M. incognita* with a root knot index of 3 (Plate 6). Seven cultivars *viz.,* IC 111536, Manjima, IC 117260, IC 111500, IC 111247, IC 469689 and IC 111517 were found to be susceptible with root knot index of 4 (Plate 7) and another nineteen cultivars *viz.,* IC 218900, IC 112457, IC 329360, IC 045819, IC 117308, IC 117228, Anjitha, Aruna, IC 111525, Kiran, Susthira, IC 111514, IC 329357, Arka Anamika, IC 282275, IC 305634, IC 045515, Pusa Sawani and Salkeerthi as highly susceptible with root index of 5 (Plate 8).

Table 9. Population of root knot nematode *Meloidogyne incognita* at the time of uprooting of okra and the reaction of the cultivars (Mean of three replications)

Treatments	Nematode population		Number of root knots	Root knot index	Reaction
	No./200 g soil	No./10 g root	No./ 10 g root		
T_1 - IC 218900	130.66 (15.31)	486.00 (22.07)	261.32 (16.10)	5	Highly susceptible
T_2 - IC 112457	69.00 (10.27)	425.33 (20.65)	112.00 (10.63)	5	Highly susceptible
T_3 - IC 329360	83.6 (11.01)	478.33 (21.89)	152.66 (12.40)	5	Highly susceptible
T_4 - IC 111536	86.00 (11.20)	394.00 (19.87)	97.00 (9.90)	4	Susceptible
T_5 - IC 045819	`57.33 (10.24)	275.33 (16.62)	115.66 (10.80)	5	Highly susceptible
T_6 - IC 111507	48.00 (8.7)	79.00 (8.94)	22.66 (4.87)	3	Moderately resistant
T_7 - Manjima	57.00 (10.23)	205.33 (14.36)	85.00 (9.27)	4	Susceptible
T_8 - IC 117308	74.66 (10.31)	405.67 (20.170)	151.00 (12.33)	5	Highly susceptible
T_9 - IC 117228	77.00 (10.58)	438.33 (20.96)	123.00 (11.14)	5	Highly susceptible
T_{10} - Anjitha	86.66 (11.13))	457.00 (21.40)	143.00 (12.00)	5	Highly susceptible

(Contd……)

85

Treatments	Nematode population		Number of root knots	Root knot index	Reaction
	No./200 g soil	No./10 g root	No./ 10 g root		
T_{11} - IC 117260	47.33 (8.20)	120.67 (11.03)	51.33 (7.23)	4	Susceptible
T_{12} - Aruna	124.66 (14.43)	480.33 (21.94)	220.66 (14.89)	5	Highly susceptible
T_{13} -Varsha Uphar	31.66 (4.54)	76.67 (8.81)	24.20 (5.16)	3	Moderately resistant
T_{14} - IC 117251	36.12 (5.41)	62.67 (7.98)	28.33 (5.42)	3	Moderately resistant
T_{15} - IC 111525	67.30 (10.26)	366.67 (19.17)	124.66 (11.21)	5	Highly susceptible
T_{16} - Kiran	96.00 (10.31)	214.33 (14.67)	105.33 (10.31)	5	Highly susceptible
T_{17} - IC 111500	56.00 (10.14)	118.33 (10.92)	66.66 (8.23)	4	Susceptible
T_{18} - Susthira	135.30 (16.23)	485.33 (22.05)	266.00 (16.34)	5	Highly susceptible
T_{19} - IC 111247	42.60 (7.23)	94.33 (9.76)	61.66 (7.91)	4	Susceptible
T_{20} - IC 111514	75.00 (10.32)	418.00 (20.47)	121.00 (11.05)	5	Highly susceptible
T_{21} - IC 329357	77.00 (10.58)	457.67 (21.42)	108.33 (10.45)	5	Highly susceptible

(Contd….)

86

Treatments	Nematode population		Number of root knots	Root knot index	Reaction
	No./200 g soil	No./10 g root	No./ 10 g root		
T_{22} - IC 117238	34.33 (5.11)	55.00 (7.48)	19.66 (4.55)	3	Moderately resistant
T_{23} - Arka Anamika	80.00 (10.64)	421.00 (20.54)	146.00 (12.21)	5	Highly susceptible
T_{24} - IC282275	96.33 (11.61)	350.33 (18.74)	104.66 (10.28)	5	Highly susceptible
T_{25} - IC 469689	45.66 (6.92)	228.67 (15.15)	76.00 (8.78)	4	Susceptible
T_{26} - IC 111517	41.00 (5.82)	190.00 (13.82)	98.00 (9.95)	4	Susceptible
T_{27} - IC 305634	56.00 (10.14)	361.67 (19.04)	131.33 (11.50)	5	Highly susceptible
T_{28} - Pusa Sawani	125.33 (14.32)	457.67 (21.42)	108.33 (10.45)	5	Highly susceptible
T_{29}- Salkeerthi	109.66 (12.11)	467.33 (21.64)	135.00 (11.66)	5	Highly susceptible
T_{30} - IC 045515	55.66 (9.27)	280.00 (16.76)	104.33 (10.26)	5	Highly susceptible
CD Value (At 0.05 level)	4.53	7.59	5.09		

Values in the paranthesis are SQRT transformed values

Plate 6. Okra cultivars moderately resistant to *Meloidogyne incognita*

T_6 - IC 111507

T_{13} - Varsha Uphar

T_{14} - IC 117251

T_{22} - IC 117238

Plate 7. Okra cultivars susceptible to *Meloidogyne incognita*

T_4 - IC 111536

T_7 - Manjima

T_{11} - IC 117260

T_{17} - IC 111500

(Contd…)

T_{19} - IC 111247

T_{25} - IC 469689

T_{26} - IC 111517

Plate 8. Okra cultivars highly susceptible to *Meloidogyne incognita*

T_1 - IC 218900

T_2 - IC 112457

T_3 - IC 329360

T_5 - IC 045819

(Contd...)

T_8 - IC 117308

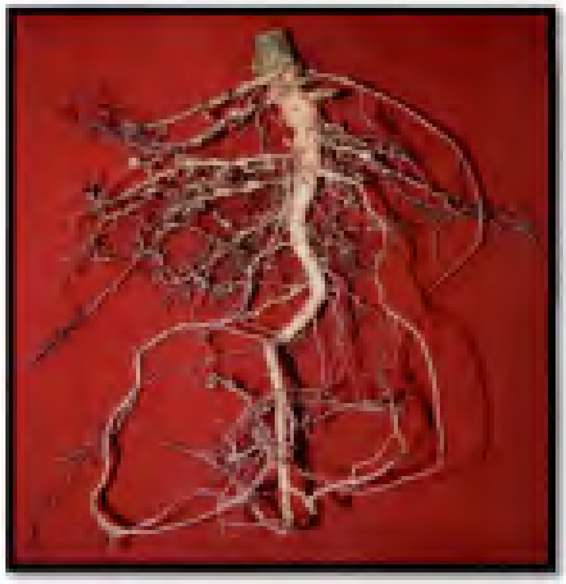
T_9 - IC 117228

T_{10}- Anjitha

T_{12} - Aruna

(Contd…)

T_{15} - IC 111525



T_{16} - Kiran

T_{18}- Susthira

T_{20} - IC 111514

(Contd..)

T_{21} - IC329357

T_{23} - Arka Anamika

T_{24} - IC 282275

T_{27} - IC 305634

(Contd…)

T_{28} - Pusa Sawani

T_{29} - Salkeerthi

T_{30} - IC 045515

4.2. BIOCHEMICAL BASES OF RESISTANCE

Biochemical basis of resistance of different okra cultivars to root knot nematode, *M. incognita* were ascertained by estimating total phenol content, peroxidase activity, total sugar and reducing sugars in the okra roots at three months after inoculation. The results are presented in Table 10 and 11.

4.2.1. Total phenol content

Total phenol content varied significantly among the okra cultivars evaluated. The mean total phenol content ranged from 0.85 mg g^{-1} to 2.03 mg g^{-1} in different cultivars. Under inoculated condition, mean total phenol content ranged from 0.91 mg g^{-1} to 3.06 mg g^{-1}. Moderately resistant cultivar IC 117238 recorded the highest phenol content of 2.03 mg g^{-1} in control and 3.06 mg g^{-1} under inoculated condition, while IC 282275 recorded the lowest total phenol content of 0.85 mg g^{-1} and 0.91 mg g^{-1} under control and inoculated condition. The per cent increase of total phenol content was maximum in IC 117238 (50.74 per cent) followed by Varsha Uphar (49.45 per cent), IC 111507 (47.92 per cent) and IC 117251(47.06 per cent) and these were statistically on par with each other. The per cent increase of total phenol content was minimum in highly susceptible cultivar Aruna (5.10 per cent) followed by Susthira (6.06 per cent) and IC 218900 (7.09 per cent).

4.4.2. Peroxidase activity

The peroxidase activity of okra roots of different cultivars are given in Table 10. The moderately resistant cultivar IC 117251 recorded the highest activity of 1.07 EU g^{-1} under control and 1.65 EU g^{-1} under inoculated condition. However, the highly susceptible cultivar Aruna recorded the lowest activity of 0.17 EU g^{-1} under control and 0.21 EU g^{-1} under inoculated conditions. The minimum per cent increase for peroxidase activity was found in cultivar Aruna (23.53 per cent) followed by IC 329360 (25.00 per cent) and Arka Anamika (25.93 per cent) and these are statistically

96

on par with each other. The cultivar IC 117238 recorded the highest per cent increase for the enzyme activity which was statistically on par with cultivars IC 117251 (54.21 per cent) and IC 111507 (53.07 per cent).

4.2.3. Total sugar

Statistical analysis of the data indicated that there was significant variation in the content of total sugar among the different cultivars (Table 11). The higher content of total sugar was recorded in highly susceptible cultivar Susthira (83.21 mg g^{-1}) followed by Aruna (81.23 mg g^{-1}), IC 305634 (79.22 mg g^{-1}) and Pusa Sawani (78.56 mg g^{-1}) under control. The per cent decline of total sugar was higher in cultivar Aruna (36.72 per cent) which is statistically on par with Susthira (35.61 per cent). It was followed by highly susceptible cultivars IC 305634 (34.09 per cent), Pusa Sawani (33.42 per cent), IC 045515 (33.34 per cent), Arka Anamika (33.16 per cent), IC 117228 (32.99 per cent) and IC 329360 (32.67 per cent) were statistically on par with each other. The lowest decline of total sugar was recorded in moderately resistant cultivar IC 111507 with 10.91 per cent followed by IC 117251 (11.42 per cent). All the other cultivars recorded an average decrease of total sugar content in between 12.47 and 32.54 per cent.

4.2.4. Reducing sugar

Reducing sugar estimated from okra roots are given in Table 11. Results showed that the values of reducing sugar under control and inoculated condition varied from 32.10 to 53.00 mg $g^{-1}$and 40.18 to 70.00 mg g^{-1}. The higher per cent increase of reducing sugars was recorded in cultivar IC 111525 (38.94 per cent), which was statistically on par with highly susceptible cultivars IC 045819 (37.81 per cent) and IC 117228 (37.26 per cent). The lower per cent increase of reducing sugar was recorded in moderately resistant cultivars IC 117251 (13.42 per cent) followed by Varsha Uphar (14.05 per cent). Higher content of reducing sugar recorded in highly susceptible cultivar IC 329360 with 70 mg g^{-1} and this was significantly different from other cultivars. Minimum content of reducing sugar was observed in cultivars IC 117260 (susceptible), IC 111507 (moderately resistant) and IC 469689 (susceptible) with 40.18 mg g^{-1}, 40.83 mg g^{-1} and 41.06 mg g^{-1} respectively

98

Table 10. Influence of *Meloidogyne incognita* infestation on phenol content and peroxidase activity of okra cultivars at three months after inoculation

Treatments	Total phenol (Mean of three replications)			Peroxidase activity (Mean of three replications)		
	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent increase over control	Control (EU g^{-1})	Inoculated (EU g^{-1})	Per cent increase over control
T_1 - IC 218900	1.27	1.36	7.09	0.23	0.30	30.43
T_2 - IC 112457	1.32	1.49	12.88	0.21	0.29	38.10
T_3 - IC 329360	1.39	1.58	13.67	0.32	0.40	25.00
T_4 - IC 111536	1.49	1.62	8.72	0.45	0.65	44.44
T_5 - IC 045819	1.66	2.16	30.12	0.28	0.38	35.71
T_6 - IC 111507	1.92	2.84	47.92	0.90	1.37	53.07
T_7 - Manjima	1.53	1.95	27.45	0.48	0.68	41.67
T_8 - IC117308	1.16	1.27	9.48	0.18	0.23	27.78
T_9 - IC117228	1.45	1.68	15.86	0.31	0.42	35.48
T_{10} - Anjitha	1.51	1.72	13.91	0.26	0.35	34.62

(Contd…)

Treatments	Total phenol (Mean of three replications)			Peroxidase activity (Mean of three replications)		
	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent increase over control	Control (EU g^{-1})	Inoculated (EU g^{-1})	Per cent increase over control
T_{11} - IC 117260	1.56	2.01	28.85	0.54	0.79	46.30
T_{12} - Aruna	0.98	1.03	5.10	0.17	0.21	23.53
T_{13} .VarshaUphar	1.82	2.72	49.45	1.06	1.56	47.17
T_{14} - IC 117251	1.87	2.75	47.06	1.07	1.65	54.21
T_{15} - IC 111525	1.39	1.53	10.07	0.19	0.25	31.58
T_{16} - Kiran	1.32	1.48	12.12	0.24	0.31	29.17
T_{17} - IC 111500	1.70	2.09	22.94	0.23	0.32	39.13
T_{18} - Susthira	1.65	1.75	6.06	0.42	0.63	50.00
T_{19} - IC 1112476	1.80	2.27	26.11	0.44	0.64	45.45
T_{20} - IC 111514	1.43	1.58	10.49	0.22	0.29	31.82
T_{21} - IC329357	1.25	1.41	12.80	0.29	0.39	34.48

(Contd….)

Treatments	Total phenol (Mean of three replications)			Peroxidase activity (Mean of three replications)		
	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent increase over control	Control (EU g^{-1})	Inoculated (EU g^{-1})	Per cent increase over control
T_{22} - IC 117238	2.03	3.06	50.74	1.02	1.59	55.88
T_{23} - Arka Anamika	1.32	1.44	9.09	0.27	0.34	25.93
T_{24} - IC282275	0.85	0.91	7.06	0.32	0.42	31.25
T_{25} - IC 469689	1.69	2.11	24.85	0.49	0.68	38.78
T_{26} - IC111517	1.72	2.15	25.00	0.53	0.76	43.70
T_{27} - IC 305634	1.41	1.53	8.51	0.29	0.37	27.59
T_{28} - Pusa Sawani	1.59	1.72	8.18	0.38	0.51	34.21
T_{29} - Salkeerthi	1.28	1.40	9.37	0.35	0.46	31.43
T_{30} - IC 045515	1.38	1.55	12.32	0.31	0.42	35.48
CD Value (At 0.05 level)	0.18	0.23	3.92	0.05	0.09	3.12

101

Table 11. Influence of *Meloidogyne incognita* infestation on total sugar and reducing sugar content of okra cultivars at three months after inoculation

Treatments	Total sugar (Mean of three replications)			Reducing sugar (Mean of three replications)		
	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent decrease over control	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent increase over control
T_1 - IC 218900	111.20	75.02	32.54	46.55	62.24	33.71
T_2 - IC 112457	99.67	73.92	25.84	47.56	60.48	27.17
T_3 - IC 329360	109.89	73.99	32.67	53.00	70.00	32.08
T_4 - IC 111536	77.23	64.55	16.42	37.89	44.79	18.21
T_5 - IC 045819	108.00	73.26	32.17	40.23	55.44	37.81
T_6 - IC 111507	63.23	56.33	10.91	35.19	40.83	16.03
T_7 - Manjima	78.22	66.33	15.20	42.62	50.20	17.79
T_8 - IC 117308	115.00	78.00	32.17	42.41	55.15	30.04
T_9 - IC 117228	98.50	66.00	32.99	40.77	55.96	37.26
T_{10} - Anjitha	101.25	72.23	28.66	45.11	60.20	33.45

(Contd…)

Treatments	Total sugar (Mean of three replications)			Reducing sugar (Mean of three replications)		
	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent decrease over control	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent increase over control
T_{11} - IC 117260	62.21	53.23	14.43	33.63	40.18	19.48
T_{12} - Aruna	128.36	81.23	36.72	50.56	65.99	30.52
T_{13} .Varsha Uphar	72.23	63.22	12.47	39.51	45.06	14.05
T_{14} - IC 117251	70.22	62.20	11.42	38.44	43.60	13.42
T_{15} - IC 111525	85.67	63.42	25.97	35.26	48.99	38.94
T_{16} - Kiran	93.33	68.00	27.14	32.10	41.39	28.94
T_{17} - IC 111500	71.56	59.33	17.09	36.33	42.61	17.29
T_{18} - Susthira	129.23	83.21	35.61	50.16	65.37	30.32
T_{19} - IC 1112476	96.00	65.59	31.68	39.00	52.27	34.03
T_{20} - IC 111514	107.00	74.50	30.37	48.56	60.78	25.16
T_{21} - IC329357	96.17	69.25	27.99	40.89	49.94	22.13

(Contd…)

Treatments	Total sugar (Mean of three replications)			Reducing sugar (Mean of three replications)		
	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent decrease over control	Control (mg g^{-1})	Inoculated (mg g^{-1})	Per cent increase over control
T_{22} - IC 117238	62.22	55.23	11.23	36.11	42.19	16.84
T_{23} - Arka Anamika	104.50	69.85	33.16	40.00	52.22	30.55
T_{24} - IC282275	108.17	74.75	30.90	47.65	59.33	24.51
T_{25} - IC 469689	79.23	65.66	17.13	35.00	41.06	17.31
T_{26} - IC111517	85.00	69.33	18.44	40.23	48.24	19.91
T_{27} - IC 305634	120.20	79.22	34.09	48.17	61.28	27.22
T_{28} - Pusa Sawani	118.00	78.56	33.42	45.60	58.28	27.81
T_{29} - Salkeerthi	103.50	74.50	28.02	42.87	57.61	34.39
T_{30} - IC 045515	107.75	71.83	33.34	35.66	47.25	32.50
CD value (At 0.05 level)	2.54	2.91	1.10	1.29	1.89	2.76

4.3. CORRELATION OF BIOCHEMICAL PARAMETERS WITH ROOT KNOT NEMATODE INFESTATION AND POPULATION

Statistical analysis was carried out to ascertain the correlation between biochemical parameters at the time of uprooting and nematode population in root and soil. The results are presented in Table 12.

4.3.1 Total phenol content

Total phenol content exhibited negative and significant correlation at 0.01 per cent level with number of root knots (-0.59), root knot index (-0.79), nematode population in root (-0.88) as well as in soil (-0.68).

4.3.2. Peroxidase activity

Peroxidase activity had significant and negative correlation at 0.01 per cent level with number of root knots (-0.60), root knot index (-0.66), nematode population in root (-0.76) as well as in soil (-0.57).

4.3.3. Total sugar

The total sugar content showed significant and positive correlation with number of root knots (0.66), root knot index (0.80), and nematode population in root (0.88) as well as in soil (0.68). These were significant at 0.01 per cent level.

4.3.4. Reducing sugars

The content of reducing sugars showed negative correlation with number of root knots (0.49), root knot index (0.71), and nematode population in root (0.76) as well as in soil (0.63). These were found significant at 0.01 per cent level.

Table 12. Correlation of biochemical parameters with population of root knot nematode

	Nematode population in soil	Nematode population in root	Root knot number	Root knot index	Total phenol	Peroxidase	Total sugars
Nematode population in root	0.72**						
Root knot number	0.82**	0.55**					
Root knot index	0.84**	0.82**	0.69**				
Total phenol	-0.68**	-0.88**	-0.59**	-0.79**			
Peroxidase	-0.57**	-0.76**	-0.60**	-0.66**	0.79**		
Total sugars	0.68**	0.88**	0.66**	0.80**	-0.72**	-0.73**	
Reducing sugars	0.63**	0.76**	0.49**	0.72**	-0.74*	-0.71**	0.75**

**. Correlation is significant at 0.01 level (2-tailed).

Discussion

5. DISCUSSION

Root knot nematodes are one among the most economically destructive group of plant parasitic nematodes causing damage and yield losses on vegetable crops, especially okra. There is a need to develop new management techniques to reduce nematode population below threshold levels. Use of chemical nematicides is the main practice to manage nematodes but improper use results in environmental hazards. Development of okra cultivars with nematode resistance is an effective management tool which is environmentally safe and economically feasible.

As the information on existence of resistance in okra cultivars is meagre, the present investigation was made to screen different okra cultivars against *Meloidogyne incognita.*

Thirty okra cultivars comprising twenty one accessions from NBPGR Regional Station, Thrissur, eight released varieties and a highly susceptible check (Arka Anamika) were screened for their reaction to root knot nematode *M.incognita.* Okra plants were inoculated with *M.incognita* @ one second stage juvenile per gram of soil after two weeks of seed germination. Biometric characters like plant height, number of leaves, number of flowers, number of fruits, fruit weight were taken at fortnightly intervals from the time of inoculation till uprooting. Three months after inoculation all the plants were uprooted and the nematode damage in the root system of all the cultivars was studied. At the time of uprooting shoot weight and root weight were recorded. The biochemical parameters like total sugar content, reducing sugar, total phenol content and peroxidase (PO) activity were estimated at three months after inoculation using standard procedure. The results of the investigation are discussed in this chapter.

5.1. SCREENING OF OKRA CULTIVARS AGAINST ROOT KNOT NEMATODE, *Meloidogyne incognita*

5.1.1. Biometric characters of okra cultivars

The results presented in Table 3, 4, 5, 6, 7 and 8 revealed that all the cultivars showed a decreasing trend in terms of height, number of leaves, flowers and fruits and weight of fruits, shoot and root compared to control plants.

The mean height of the plants at the time of inoculation ranged from 9.58 cm to 13.58 cm. IC 117238, the moderately resistant cultivar recorded minimum reduction of 8.02 per cent and this was statistically on par with other moderately resistant cultivars like Varsha Uphar and IC 117251 with 9.31 and 13.67 per cent. Highest decrease in plant height was recorded in Susthira, the highly susceptible cultivar with 46.85 per cent followed by IC 117228 (42.77 per cent) and Arka Anamika (41.32 per cent).

The reduction in number of leaves of okra cultivars at the time of uprooting was ranged from 18.87 to 70.25 per cent. The maximum reduction in number of leaves was recorded in the highly susceptible cultivars Susthira (70.25 per cent), which was statistically on par with Arka Anamika (66.84 per cent). The minimum per cent decrease in number of leaves was observed in moderately resistant cultivar IC 117238 (18.87 per cent), which was statistically on par with moderately resistant cultivar IC 117251 (21.91 per cent) and these were significantly different from other cultivars.

Moderately resistant cultivars IC 117238 recorded minimum reduction in number of flowers with 16.89 per cent and this was followed by Varsha Uphar with 18.81 per cent. Maximum reduction in number of flowers was recorded in highly susceptible cultivar Susthira with 48.12 per cent followed by Pusa Sawani and Salkeerthi with 48.06 per cent and 46.70 per cent.

Minimum reduction in number of fruits was recorded in moderately resistant cultivars IC 117238 with 18.33 per cent followed by IC 111507 and

109

Varsha Uphar with 19.00 and 19.48 per cent. Highly susceptible cultivar Susthira recorded maximum reduction in number of fruits with 49.76 per cent followed by Arka Anamika with 49.75 and these are statistically on par with each other.

Susceptible cultivar IC 111536 scored maximum reduction in fruit weight with 11.16 per cent which is statistically on par with highly susceptible cultivar IC 305634 with 10.25 per cent. Moderately resistant cultivar IC 117238 recorded minimum reduction with 1.70 per cent followed by IC 117251 with 1.90 per cent.

Moderately resistant okra cultivars recorded lesser reduction in number of fruits than susceptible and highly susceptible cultivars. Maximum reduction of 19.20 and 12.10 per cent were recorded in the highly susceptible cultivars Sharmeeli and Anmol respectively. Significant variations in the reduction of fruit weight and yield were observed among the different categories of okra cultivars. Minimum reduction of 0.80 and 2.90 per cent were recorded in moderately resistant cultivar, Sanam. Highly susceptible cultivar Sharmeeli recorded maximum reductions in fruit weight and yield with 18.5 and 34.1 per cent (Mukhtar *et al.*, 2017).

Odeyemi *et al.* (2016) also reported that okra accessions CEN/009, NG/SA/DEC/07/498, NHGB/09/055 and NG/AA/SEP/09/038 which were susceptible to *M. incognita* had reduced yield compared to control whereas accessions *viz.,* NG/AA/SEP/09/040, NG/TO/JUN/09/007, NHGB/09/057 and NHGB/10/048 which were reported to be resistant showed no yield loss compared to control.

The reduction in shoot weight of different okra cultivars ranged from 24.23 to 72.08 per cent. Maximum reduction was recorded in highly susceptible cultivars Susthira with 72.08 per cent followed by Aruna and IC 329360 with 69.40 and 65.16 per cent. Minimum reduction was recorded in highly susceptible cultivar Anjitha with 24.23 per cent which is statistically on par with moderately resistant cultivars IC 117238 (25.68 per cent) followed by Varsha Uphar (27.41 per cent) and IC 111507 (27.72 per cent).

Similar results were obtained by Mukhtar *et al.* (2013) with root knot nematode *M. incognita* that caused significant reduction in various growth parameters of okra cultivars to varying levels over their respective controls. Highly susceptible cultivar Sharmeeli recorded maximum decrease in shoot length (21.71 per cent) and shoot weight (38.36 per cent), while moderately resistant cultivar Sanam, Ikra-1 and Ikra-2 recorded minimum decrease in shoot weight with 2.88, 4.48, 5.40 per cent respectively. Minimum decrease in shoot length was recorded in moderately resistant cultivars Sanam (2.11 per cent) and Dikshah (3.07 per cent).

Root weight of inoculated and control plants of different cultivars at the time of uprooting ranged from 13.53 to 29.73 g and 16.06 to 40.85 g respectively. Moderately resistant cultivar IC 117251 recorded minimum decrease with 3.15 per cent and this was statistically on par with moderately resistant cultivar IC 111507 (3.53 per cent) followed by highly susceptible cultivar Kiran (5.93 per cent). Maximum decrease in root weight was observed in highly susceptible cultivars Arka Anamika with 36.56 per cent followed by IC 117308 and Salkeerthi with 36.47 and 35.00 per cent respectively.

Nayak and Pandey (2015) reported that the infestation of *M. incognita* resulted in decrease in root weight of brinjal plants compared to control plants. Moderately resistant cultivar Pusa Kranti scored lowest decrease in root weight with 28.68 per cent compared to highly susceptible cultivar Pusa Purple Long with 31.67 per cent.

The reductions in biometric parameters in highly susceptible cultivars are attributable to root injury due to penetration and feeding by the nematodes which cause impairment of root systems to absorb water. The formation and development of giant cells in the roots by *M. incognita* extensively disrupt xylem tissues and greatly retard absorption and upward movement of water and nutrients. The infestation also greatly reduces permeability of roots to water. The infestation induces the formation of nurse cells and regulates greater translocation

111

of photosynthates towards infested root tissue while other parts (foliage) experience shortage (Wyss, 2002). This results in poor growth of foliage subsequently leading to decreased production (Kayani *et al.*, 2017). In resistant or moderately resistant cultivars, juveniles are failed to induce formation of giant cells in the roots and they will either starve or migrate out and the plant growth is not affected (Mukhtar *et al.*, 2014)

5.1.2. Nematode population

5.1.2.1. Number of root knots

Among the 30 cultivars screened the moderately resistant cultivar IC 117238 recorded the lowest root knot number of 19.66 followed by IC 111507 with 22.66, whereas the highly susceptible cultivar Susthira recorded highest root knot number of 266.00 which was found to be statistically on par with highly susceptible cultivar IC 218900 (261.32). Rest of the cultivars were reported to have root knots in between 24.20 and 220.66.

Formation of root knots is the most characteristic symptom of *M.incognita* infestation. The second stage juveniles of root knot nematodes penetrate to the epidermis and migrate through the root cortex. They establish permanent feeding sites in the vascular parenchyma that provides nutrition for development and multiplication. The feeding sites formed in the differentiation zone of the root and thus cause nuclear division without cytokinesis. This process leads to formation of large, multinucleate cells, called giant cells. The plant cells around the feeding site divide, multiply and swell, consequently root knots or galls are formed in the roots. These giant cells act as specialised sinks and supply nutrients to the nematodes for their growth and development (Abad *et al.*, 2009).

The results thus obtained are in agreement with the findings of Nayak and Sharma (2013) and Mukhtar *et al.* (2014). They also opined that resistance/susceptibility to *M. incognita* could be related to the variation in number of root knots. Hence the cultivars with low root knot number were considered to be resistant compared to other cultivars with high root knot number.

5.1.2.2. Root knot index

Cultivars were categorised as per the 1-5 scale of root knot index proposed by Devi *et al.* (2014). Based on the root knot number and root knot index the cultivars were categorised as moderately resistant, susceptible and highly susceptible. Data regarding root knot index are presented in Table 9.

Classification of resistance based on root knot number

Sl. No.	No. of galls/ plant	Root knot index	Reaction
1	No galls	1	Highly resistant
2	1-10 galls	2	Resistant
3	11-30 galls	3	Moderately resistant
4	31-100 galls	4	Susceptible
5	101 and above	5	Highly susceptible

In the present investigation, none of the cultivars evaluated were found to be highly resistant or resistant with root knot index of 1or 2, whereas, four cultivars *viz.*, IC 117238, IC 117251, IC 111507 and Varsha Uphar with root knot index 3 could be rated as moderately resistant to *M. incognita.* Similar results were obtained by Mondal *et al.* (2016) in which the cultivar IC 117238 was reported as moderately resistant to *M. incognita*. Moderate resistance of Varsha Uphar was also reported by Sheela *et al.* (2006).

Seven cultivars *viz.,* IC 111536, Manjima, IC 117260, IC 111500, IC 111247, IC 469689 and IC 111517 were found to be susceptible with root knot index 4. Nineteen cultivars *viz.,* IC 218900, IC 112457, IC 329360, IC 045819, IC 117308, IC 117228, Anjitha, Aruna, IC 111525, Kiran, Susthira, IC 111514, IC 329357, Arka Anamika, IC 282275, IC 305634, IC 045515, Pusa Sawani and Salkeerthi were observed as highly susceptible with root knot index 5. Rekha and Gowda (2000) also reported that Arka Anamika was susceptible to *M. incognita,* whereas it was reported to be moderately resistant to *M. incognita* in Pakistan (Hussain *et al.*, 2016b). Susceptibility of Pusa Sawani was also reported by Das and Sinha (1998) and Sheela *et al.* (2006).

5.1.2.3. Nematode population in root

Highest population was recorded from IC 218900 with an average of 486.00 per 10 g root followed by Susthira (485.33), Aruna (480.33) and IC 329360 (478.33). These were statistically on par. The lowest nematode population was recorded from IC 117238 with 55.00 per 10 g root followed by IC 117251 and Varsha Uphar with 62.67 and 76.67 per 10 g root respectively. Nematode population in all other cultivars varied between 79.00 to 467.33 per 10 g root.

Development and reproduction of *Meloidogyne* spp. was reflected by resistance and susceptibility of the host plants (Khan *et al.*, 2004), as the present study indicated that root population was higher in highly susceptible cultivars as compared to the moderate resistant cultivars. The juveniles in a resistant plant are either incapable of penetrating the roots or their death may be due to the toxic environment for nematode penetration and multiplication.

5.1.2.4. Nematode population in soil

The mean nematode population in soil ranged from 31.66 to 135.30 per 200 g soil. The highest population was obtained from the cultivar Susthira with 135.30 per 200 g soil followed by IC 218900, Pusa Sawani and Aruna with an average nematode population of 130.66, 125.33 and 124.66 per 200 g soil respectively. The lowest population of nematodes was recorded from Varsha Uphar (31.66/200 g soil) followed by IC 117238 and IC 117251 with an average population of 34.33 and 36.12 per 200 g soil, which were statistically on par. Nematode population from rest of the cultivars varied between 41.00 and 109.66 per 200 g soil.

The results pointed out that intensity of root knots and soil population is inversely proportional. The penetration and development of second stage juveniles

114

is influenced by the type of host plant (David, 1980) and it is positively correlated with host susceptibility (Veena *et al*., 1985). The higher population of nematodes in highly susceptible plants reveals that susceptible hosts allow the juveniles to express their full developmental potential, whereas development is suppressed in resistant hosts (Nelson *et al*., 1990).

The nematode resistance in host plants was manifested by reduced rates of nematode reproduction, egg masses and consequently, low nematode population densities than that of a susceptible one. Thus results of present study is in agreement with the report by Khan (1994) that the formation of galls on plant roots increased significantly on the susceptible genotypes compared with resistant genotypes there by affecting plant performance.

5.2. BIOCHEMICAL BASES OF RESISTANCE

Analysis of biochemical parameters such as total phenol, peroxidase (PO), total sugar and reducing sugar in okra roots infested with *M.incognita* implicated the physiological response in cultivars against root knot nematode. The relationship between the biochemical parameters and the level of root knot infestation brought out in the study are discussed below.

5.2.1 Total phenol

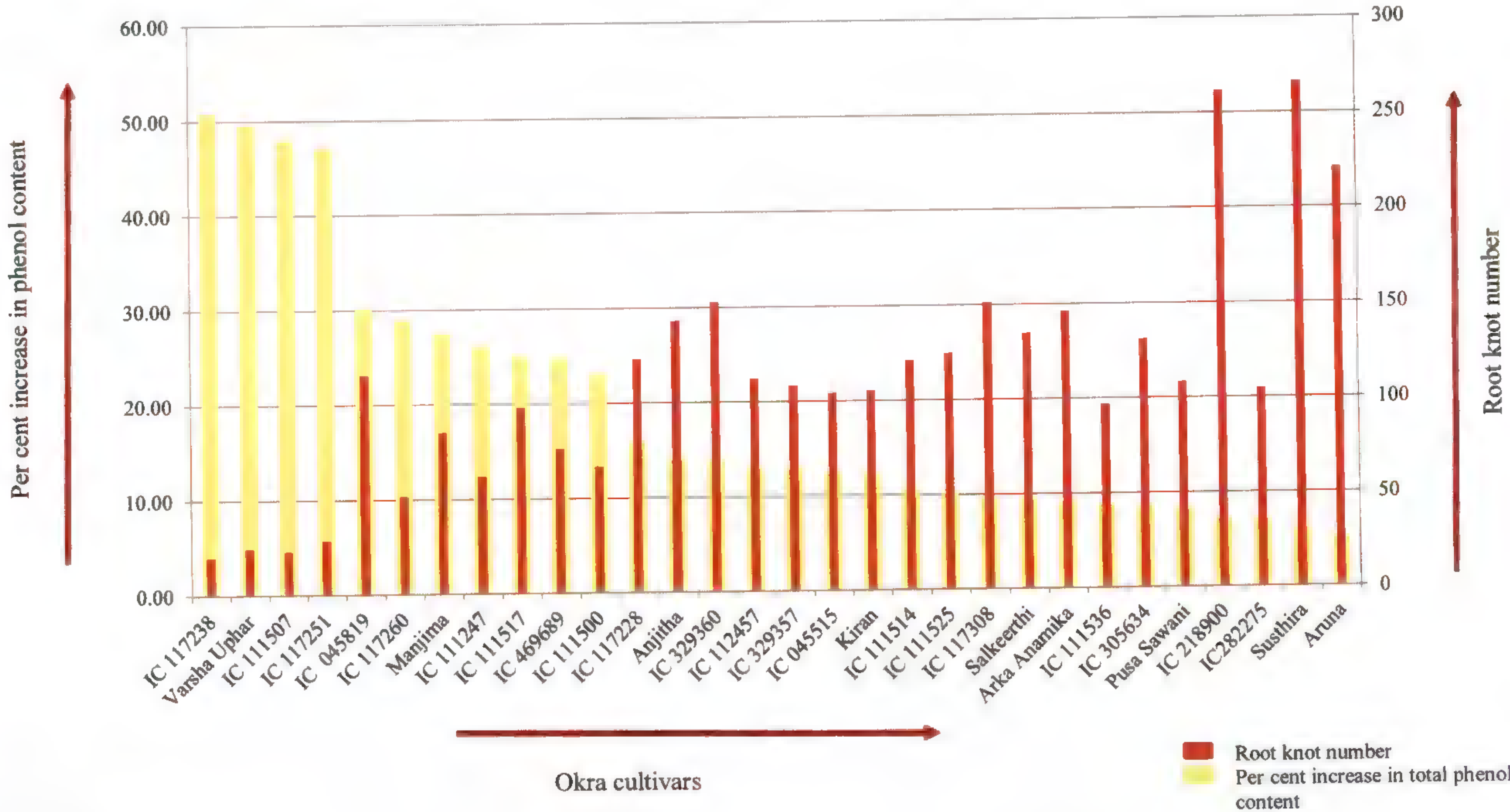
Phenolic compounds are considered as non-specific defence metabolites against the pathogen and resistant plants have the tendency to accumulate these metabolites in higher amounts than in susceptible ones following infestation (Alam *et al.*, 1991).The increase in phenolics in resistant plants is due to high activity of β-glycosidase, which converts non-toxic phenolic glycosides to toxic phenolics which are inhibitory to the pathogen. Nematodes are able to do this by secreting β-glycosidase into the host tissue (Cruickshank *et al.*, 1974). Narayana and Reddy (1980) also reported that an increased phenolic content was considered to be a contributory factor in the resistance to various nematode infections

The higher content of total phenol was recorded by moderately resistant cultivars than the susceptible and highly susceptible cultivars. The moderately resistant cultivar IC 117238 scored highest total phenol content of 3.06 mg g^{-1} followed by IC 111507 with 2.84 mg g^{-1}. These are statistically on par with each other. The lowest total phenol content was recorded from IC 282275 (highly susceptible) with 0.91 mg g^{-1} followed by Aruna (highly susceptible) with 1.03 mg g^{-1}. The per cent increase of total phenol content was higher in moderately resistant cultivar IC 117238 with 50.74 per cent and lower in highly susceptible cultivar Aruna with 5.10 per cent (Fig 1).

The increased phenolic content may be the reason for the partial resistance to nematode infestation in these moderately resistant cultivars. Moreover, these cultivars had innately high phenol content which further increased by nematode infestation, but susceptible and highly susceptible cultivars the phenol content was

116

Fig. 1. Per cent change in phenol content on number of root knots of different okra cultivars



less and nematode infestation could not produce a substantial increase in it, which made them susceptible to the infestation.

Similarly enhanced total phenol contents were also demonstrated by Sharma and Trivedi (1996) who reported higher total phenolic content in okra cultivar Punjab 7 (less susceptible) than Pusa Sawani (highly susceptible) with 390 mg g^{-1} and 380 mg g^{-1} respectively. Likewise, Mohanta and Mohanty (2012) reported *M.incognita* infested roots of okra cultivar L.B.H-55 recorded increased phenol by 36.92 per cent than the healthy roots. Agarwal *et al.* (1985) also reported increased phenolic content by 8.98 per cent in okra cultivar Pusa Sawani during post infection period in inoculated sample over healthy check.

Total phenol content exhibited negative and significant correlation at 0.01 per cent level with number of root knots (-0.59), root knot index (-0.79), nematode population in root (-0.88) as well as in soil (-0.68).

There is a distinct correlation between the degree of plant resistance and the phenolics present in plant tissue (Pitcher *et al.* 1960; Giebal, 1970). The hypersensitive response and elevated phenolic levels, leading to barrier deposition (e.g. Lignin), have been shown to be important in resistance to the root-knot nematode *M. incognita* (Paulson and Webster, 1972; Melillo *et al.*, 1989).

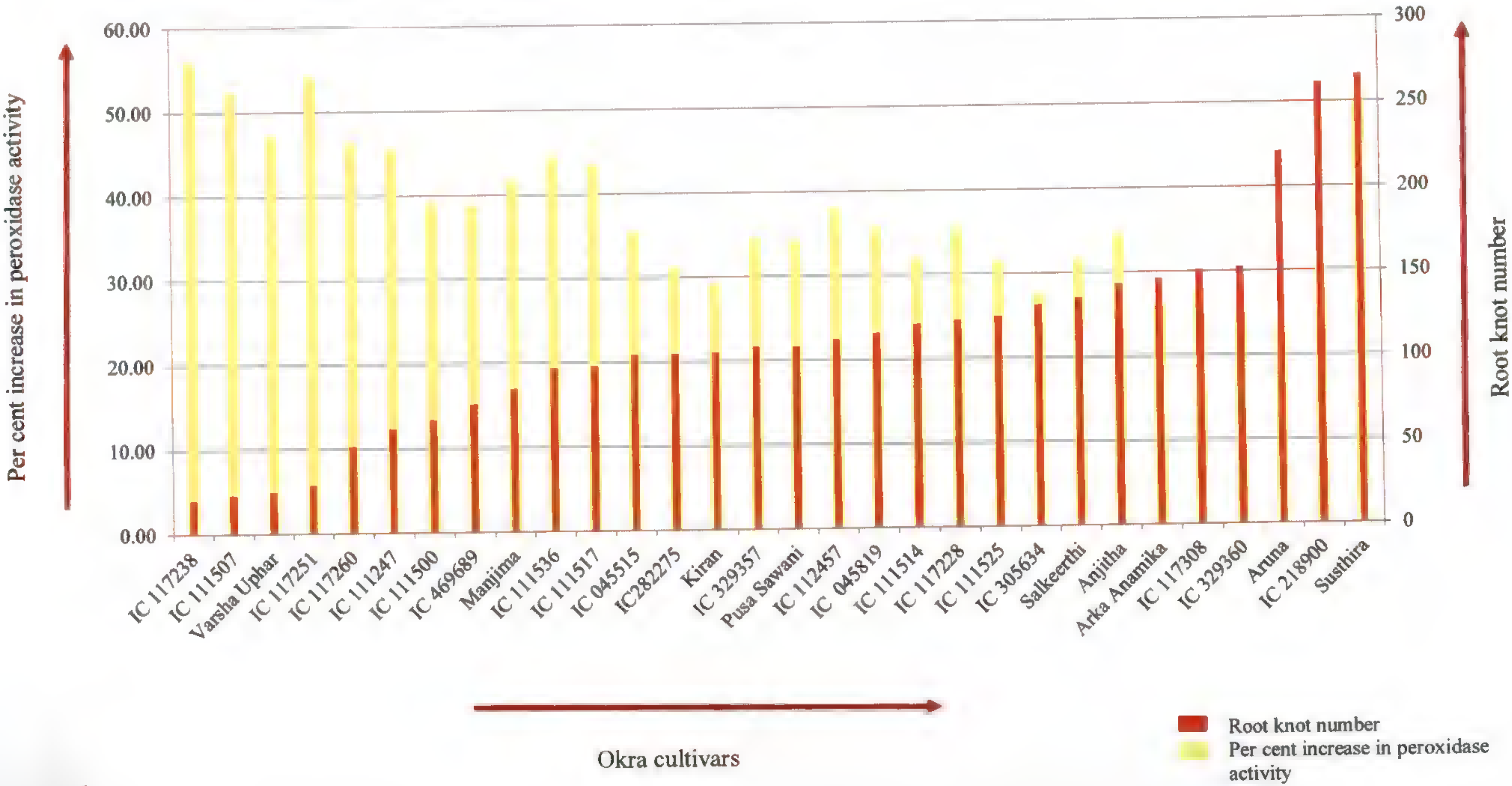
5.2.2 Peroxidase activity

Peroxidases are reported to be important in defence mechanism against plant pathogen (Ros-Barcelo *et al.*, 2003). These enzymes play an important role in modifying cell wall structure during pathogen attack by polymerizing the lignin precursors (Quiroza *et al.*, 2000) and by cross linking cell wall proteins to polysaccharides (pectin and cellulose) and polyphenols (lignin) to form an impenetrable network around the plant cells, which prevent the entry of nematode.

The present study revealed an activity difference in the enzyme peroxidase between different cultivars. The moderately resistant IC 117251 recorded higher activity of 1.65 EU g^{-1}, which was statistically on par with IC 117238 (moderately

118

Fig 2. Per cent change in peroxidase activity on number of root knots of different okra cultivars



resistant) and Varsha Uphar (moderately resistant) with 1.59 and 1.56 EU g^{-1}. Lower enzyme activity was recorded from highly susceptible cultivars Aruna (0.21 EU g) followed by IC 117308 (0.23 EU g^{-1}) and IC 111525 (0.25 EU g^{-1}). The per cent increase of peroxidase activity was maximum in moderately resistant cultivar IC 117238 with 55.88 per cent and minimum in highly susceptible cultivar Aruna with 23.53 per cent (Fig 2).

Peroxidase activity had significant and negative correlation at 0.01 per cent level with number of root knots (-0.60), root knot index (-0.66), nematode population in root (-0.76) as well as in soil (-0.57).

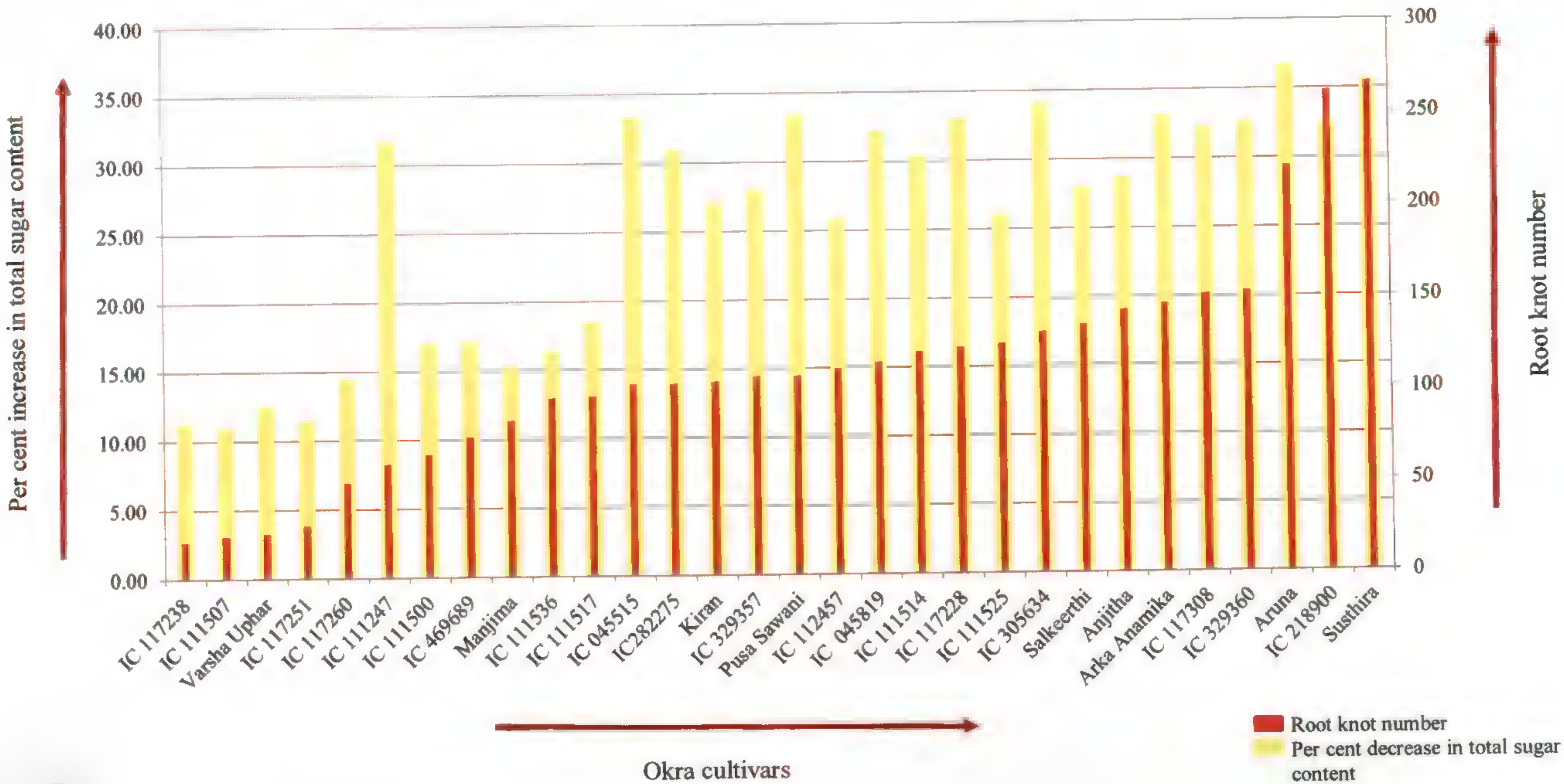
The results thus obtained were in agreement with the findings of Ahuja and Ahuja (1980). They also reported increased peroxidase activity in *M. incognita* infested roots of highly susceptible okra cv. Pusa Sawani (46.8 EU/100 g) when compared to healthy plants (37.20 EU/100 g). Similarly, Sharma and Trivedi (1996) reported higher enzyme activity of 100 per cent in okra cultivar Punjab-7 (less susceptible) than Pusa Sawani (highly susceptible) with 90 per cent. Kaur *et al.* (2013) also reported higher peroxidase activity in *M. incognita* resistant tomato cv. Hisar Lal with 70.30 EU g^{-1} than highly susceptible Hisar Arun with 1.18 EU g^{-1}.

5.2.3. Total sugar

Total sugars have been shown to play an important role during plant pathogen interactions. It is the building blocks for the synthesis of various defence chemicals such as phenolics, phytoalexins and lignin. The quantity of sugars plays an important role in resistance (Vidhyasekaran *et al.*, 1972).

Total sugar content decreased in infested roots of all okra cultivars over corresponding healthy roots. Its magnitude was more pronounced in highly susceptible cultivars than moderately resistant cultivars (Fig 3). Aruna (highly susceptible) scored maximum decrease of total sugar of 36.72 per cent followed by Susthira (Highly susceptible) with 35.61 per cent. Moderately resistant cultivars IC 111507 and IC 117251 recorded minimum decrease of 10.91 and 120

Fig. 3 Per cent change in total sugar content on number of root knots of different cultivars



121

11.42 per cent. Under inoculated condition higher content of sugar was recorded in highly susceptible cultivar Susthira (83.23 mg g^{-1}) followed by Aruna (81.21 mg g^{-1}). Cultivar IC 117260 (Susceptible) and IC 117238 (moderately resistant) recorded lower content of total sugar with 53.23 mg g^{-1} and 55.23 mg g^{-1} respectively.

The total sugar content showed significant and positive correlation with number of root knots (0.66), root knot index (0.80) and nematode population in root (0.88) as well as in soil (0.68). These were significant at 0.01 per cent level.

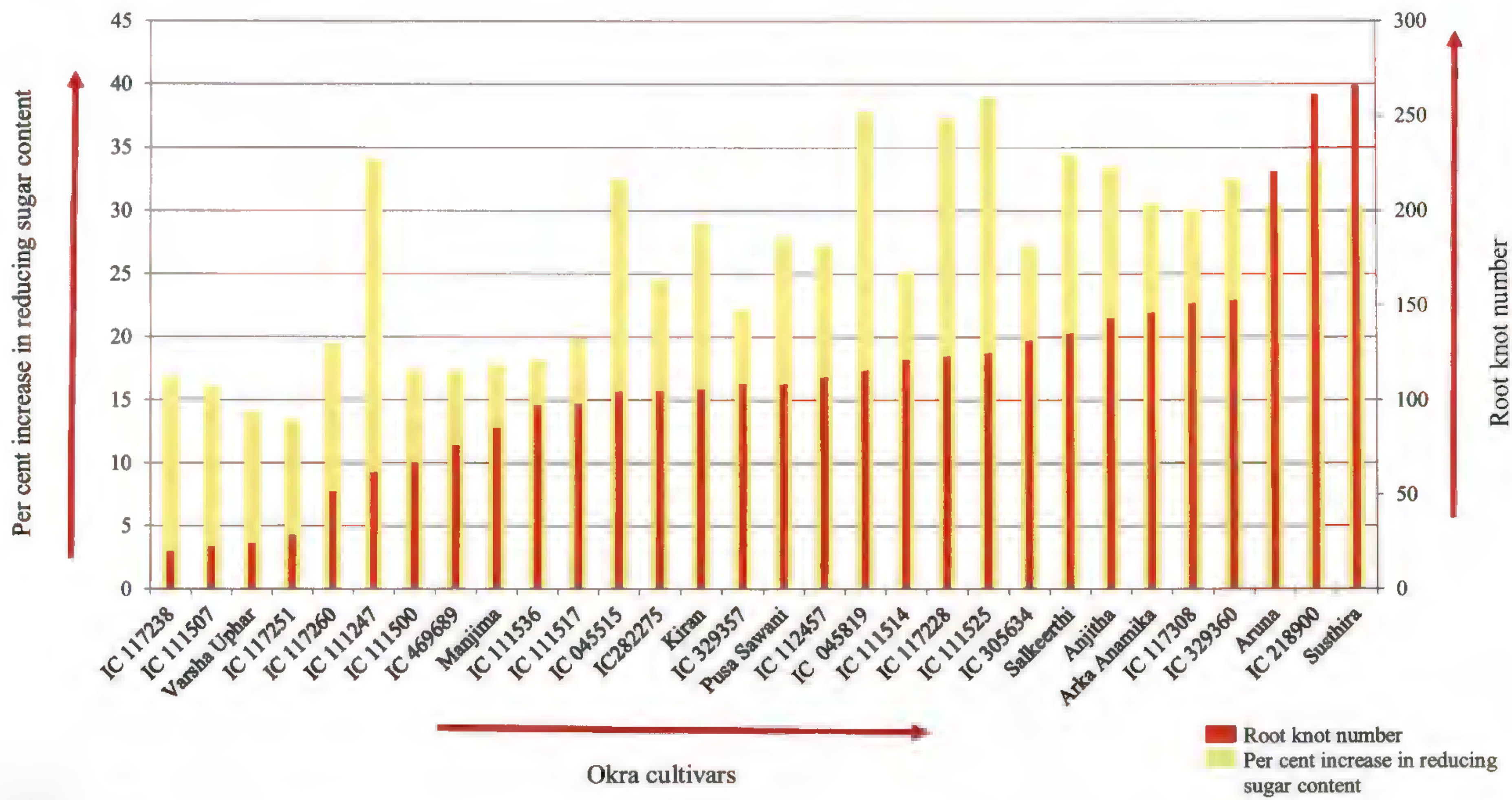
The data on total sugar content showed that cultivars with innately higher total sugar content was susceptible for nematode infestation whereas cultivars with low sugar content was moderately resistant to infestation. The rapid decline in sugar content in susceptible cultivar indicated that nematode feeding decreased the sugar in feeding sites which acts as metabolic stocks by harvesting the sugars from phloem (Hofmann *et al.*, 2008).

The results thus obtained were in agreement with the findings of Agarwal *et al.* (1985), who reported reduced total sugar content in highly susceptible okra cultivars than less susceptible ones. Similarly, Upadhyay and Banerjee (1986) reported that root knot nematode (*M. javanica*) infested chick pea cultivar K-850 showed decreased total sugar content in infested roots over their healthy counter parts. Sharma and Trivedi (1996) observed decreased total sugar content in root knot nematode infested okra cultivars *viz.,* Pusa Sawani (highly susceptible) and Punjab7 (less susceptible) over their healthy counterparts.

The decrease in total sugar content of infected roots may be due to the fact that nematode secretes or induces the production of hydrolysing enzymes such as amylase, which brings about the conversion of stored forms of sugars into its utilised form (Tayal and Agarwal, 1982). Localised strong amylase activity and lower content of sugar within the giant cells of tomato galls were reported by Orion and Bronner (1973).

122

Fig. 4. Per cent change in reducing sugar content on number of root knots of different okra cultivars



Hofmann and Grundler (2006) identified decreased sucrose content in syncytia of *Heterodera schachtii* infested roots of *Arabidopsis thaliana* at 15 days after inoculation, while the concentration were higher at 8 days after inoculation. Thus, excessive sugar supply in the initial days may be accumulated as starch that gets degraded at later stages due to higher energy requirement of nematodes. This starch reserve serves as both short-term and long-term carbohydrate storage in nematode-induced syncytia in order to buffer changing feeding pattern of the nematodes (Hofmann and Grundal, 2008; Hofmann *et al.*, 2009).

5.2.5. Reducing sugar

Considerable increase in reducing sugar was observed in nematode inoculated plants of all okra cultivars than their healthy counter parts. Higher content of reducing sugar recorded in highly susceptible cultivar IC 329360 with 70 mg g^{-1} and this is significantly different from other cultivars. Next higher reducing sugar content was recorded in Susthira (highly susceptible) and Aruna (Highly susceptible) with 65.99 mg g^{-1} and 65.38 mg g^{-1} respectively. Minimum content of reducing sugar was observed in susceptible cultivar IC 117260 (40.18 mg g^{-1}) followed by moderately resistant cultivar with 40.83 mg g^{-1}. The higher per cent increase of reducing sugar was recorded in cultivar IC 111525 (38.94 per cent) which was statistically on par with highly susceptible cultivars IC 045819 (37.81 per cent) and IC 117228 (37.26 per cent). The lower per cent increase of reducing sugar was recorded in moderately resistant cultivars IC 117251 (13.42 per cent) followed by Varsha Uphar (14.05 per cent) (Fig 4).

The results were in agreement with several workers who reported higher reducing sugar content in *M. incognita* susceptible cultivars than resistant ones. An increase in reducing sugar was observed in *Solanum melongena* variety Pusa Purple Long infested with *M.incognita* with 2.16 mg g^{-1} and accounted for 50.05 per cent increase over healthy ones (Tayal and Agarwal, 1982). Similar results were observed by Agarwal *et al.* (1985) that okra plants infested with *M. incognita* showed increased levels of reducing sugars than the healthy plants.

124

Sharma and Trivedi (1996) also reported an increase in reducing sugar content in *M. incognita* infested roots of highly susceptible (Pusa Sawani) cultivar compared to less susceptible (Punjab 7) cultivars with 484.00 and 370.00 mg g^{-1} and this accounted for 44.00 per cent increase.

The reducing sugar content showed positive correlation with number of root knots (0.49), root knot index (0.71), and nematode population in root (0.76) as well as in soil (0.63). These were found significant at 0.01 per cent level.

Infestation by the nematode may alter the metabolism of the host tissue, so that respiratory substrates move towards the site of feeding from other parts of the plants. Higher reducing sugar level present in infested tissues may be considered as a result of complex plant nematode interaction, which includes the hydrolysis of sucrose and the utilization of simple sugar by the nematode (Ganguly & Dasgupta, 1983).

125

Summary

6. SUMMARY

The present study entitled 'Response of selected okra [*Abelmoschus esculentus* (L.) Moench] cultivars to root knot nematode *Meloidogyne incognita* (Kofoid & White)' was undertaken in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during January 2016 to October 2016. Thirty okra cultivars comprising twenty one accessions from NBPGR Regional Station, Thrissur, eight released varieties and a highly susceptible check (Arka Anamika) were screened for their reaction to *M.incognita.* The objectives of the study were to screen the selected okra cultivars against root knot nematode, *Meloidogyne incognita* and to elucidate the biochemical bases of resistance.

The impact of *M. incognita* on the biometric characters of okra *viz.*, plant height, number of leaves, number of flowers, number of fruits, fruit weight, shoot weight and root weight were observed at fortnightly intervals. The biochemical parameters like peroxidase (PO) activity, total phenol content, total sugar and reducing sugar were estimated at three months after inoculation to elucidate the bases of resistance. Three months after inoculation all the cultivars were uprooted and various parameters *viz.,* number of root knots in 10 g roots and nematode population in 200 g soil and 10 g roots were recorded.

Based on the number of galls, indexing was done on 1-5 scale (1= 0 galls/plant; 2= 1-10 galls per plant; 3= 11-30 galls per plant; 4= 31-100 galls per plant; 5= more than 100 galls per plant) and the cultivars were respectively categorized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible (Devi *et al.,* 2014). None of the cultivars were highly resistant or resistant, whereas four cultivars *viz.,* IC 117238, IC 117251, IC 111507 and Varsha Uphar with mean root knot index of 3 were classified as moderately resistant. Seven cultivars *viz.,* IC 111536, Manjima, IC 117260, IC 111500, IC 111247, IC 469689 and IC 111517 with root knot index of 4 were rated as susceptible. Rest of the nineteen cultivars *viz.*, IC 218900, IC 112457, IC 329360, IC 045819, IC 117308, IC 117228, Anjitha, Aruna, IC 111525, Kiran, Susthira, IC 111514, IC 329357, Arka Anamika, IC 282275, IC 305634, IC 045515, Pusa Sawani and Salkeerthi with root knot index of 5 were classified as highly susceptible.

Biometric characters of all the cultivars exhibited significant reduction with respect to their control. The per cent reduction in these characters was higher in highly susceptible and susceptible cultivars and lower in moderately resistant cultivars. Biochemical analysis showed an increase in total phenol content and peroxidase activity in moderately resistant cultivars than susceptible cultivars. Change in total sugar and reducing sugars were higher in highly susceptible cultivars. Correlation analysis showed a significant negative correlation between total phenol content and peroxidase activity with number of root knots, root knot index, and population of *M. incognita* in root and soil. A significant positive correlation of total sugar and reducing sugar were recorded with number of root knots, root knot index, and population of *M. incognita* in root and soil.

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142

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146

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147

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* Original is not found.

148

Annexure

Annexure I

Height of okra cultivar

Treatments	Height of the cultivars (cm) (Mean of three replications)											
	Fortnightly interval after inoculation											
	1		2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C	I	C
T_1	18.20	18.41	29.33	30.63	40.50	48.32	54.33	75.21	59.57	86.52	63.23	99.65
T_2	16.47	16.60	28.37	30.26	44.40	54.23	53.40	74.20	58.97	85.62	64.03	97.56
T_3	16.77	16.98	29.37	31.20	41.03	49.23	54.53	74.61	58.53	85.69	63.97	100.23
T_4	14.57	14.71	28.63	29.68	39.43	45.62	48.63	65.32	50.53	72.51	55.43	93.20
T_5	17.30	17.56	27.87	30.10	41.23	49.52	49.43	65.35	51.60	75.62	58.63	95.96
T_6	18.37	18.52	31.75	32.26	45.27	47.52	56.53	61.23	60.30	69.32	70.10	85.21
T_7	15.17	15.31	26.53	27.98	39.43	45.69	49.53	72.23	55.47	86.53	66.40	108.50
T_8	18.47	18.63	30.13	31.26	39.47	44.62	55.57	70.68	62.17	90.23	65.07	110.20
T_9	17.57	17.78	26.27	28.56	35.77	41.92	46.55	65.23	65.47	95.36	64.27	112.30
T_{10}	16.37	16.50	25.60	26.59	36.47	43.25	55.07	69.52	58.73	78.52	66.53	102.23
T_{11}	16.80	16.90	27.73	28.92	41.27	45.52	53.67	60.23	69.30	78.93	69.30	97.50
T_{12}	17.83	17.92	29.90	32.95	39.83	43.69	57.37	65.23	63.63	78.29	74.17	125.30
T_{13}	18.27	18.40	29.47	29.78	44.13	45.93	74.23	79.53	80.80	87.59	95.43	105.23

(Contd…)

Treatments	Height of the plants (cm) (Mean of three replications) Fortnightly interval after inoculation											
	1		2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C	I	C
T_{14}	15.40	15.65	30.20	30.65	44.27	46.52	69.60	74.56	78.50	85.64	92.07	106.65
T_{15}	16.47	16.64	24.73	25.98	37.63	41.35	57.70	65.23	65.60	77.52	77.53	97.89
T_{16}	17.30	17.52	27.30	28.65	38.33	46.52	61.87	72.30	64.97	79.23	73.53	99.65
T_{17}	17.33	17.54	28.13	29.35	40.57	45.63	64.93	80.23	71.47	92.62	78.53	113.32
T_{18}	15.53	15.63	25.27	26.12	39.50	49.52	53.23	72.23	69.27	99.86	72.07	135.6
T_{19}	17.33	17.60	29.60	30.26	41.63	47.13	59.37	76.62	63.67	85.22	71.80	106.53
T_{20}	15.33	15.62	29.50	30.59	38.33	43.26	56.63	74.52	64.37	87.52	73.53	110.97
T_{21}	16.47	16.54	30.33	31.92	43.40	49.97	53.20	71.90	58.47	83.26	63.97	105.95
T_{22}	14.53	14.59	24.47	24.65	37.63	39.52	65.30	69.02	70.50	75.23	78.57	85.42
T_{23}	18.23	18.42	29.60	31.29	39.60	49.23	60.53	83.20	65.53	95.62	77.71	131.52
T_{24}	18.50	18.74	29.33	31.98	42.30	48.94	59.50	79.52	64.30	90.26	71.33	108.23
T_{25}	14.80	14.95	30.90	31.95	43.77	48.92	49.70	66.52	57.70	80.23	62.70	100.23
T_{26}	17.83	17.99	29.80	30.95	41.83	47.85	64.50	79.52	72.37	89.56	73.83	98.78
T_{27}	18.80	18.98	31.57	32.69	42.83	50.23	52.67	71.23	57.40	84.25	64.77	104.53
T_{28}	19.27	19.43	31.53	32.95	44.63	49.23	56.60	70.98	64.9	95.23	79.00	130.68
T_{29}	16.23	16.41	23.70	24.62	36.60	42.50	53.50	71.23	59.4	84.23	71.77	111.85
T_{30}	18.33	18.78	28.40	30.98	35.73	42.10	53.40	65.98	60.73	81.02	65.87	98.25

*C -Control plant I-Inoculated plant

Annexure II

Number of leaves of okra cultivars

Treatments	Number of leaves of okra cultivars (Mean of three replications)											
	Fortnightly interval after inoculation											
	1		2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C	I	C
T_1	4.00	4.06	5.00	5.20	7.00	8.07	9.67	12.31	10.33	15.20	11.46	19.12
T_2	4.00	4.12	5.00	5.26	8.00	9.53	10.00	13.20	11.33	16.35	11.40	18.02
T_3	4.33	4.55	6.00	6.56	8.00	9.87	9.33	12.65	9.65	13.65	10.28	15.03
T_4	4.68	5.00	6.00	6.89	8.67	10.75	9.00	12.98	10.33	15.64	10.28	18.45
T_5	4.00	4.15	7.00	7.56	8.67	10.11	9.67	12.43	9.33	15.32	10.25	19.05
T_6	4.33	4.43	8.67	8.99	14.00	15.20	14.00	15.65	14.58	18.01	14.53	20.12
T_7	4.59	4.85	6.00	6.59	7.67	9.26	8.67	11.52	11.00	15.42	11.35	18.06
T_8	5.33	5.42	7.00	7.56	8.33	9.64	9.67	12.26	10.61	17.21	10.56	19.23
T_9	5.00	5.23	6.00	6.59	6.67	8.09	10.00	13.26	10.41	16.09	10.42	17.56
T_{10}	5.19	5.34	7.00	7.45	8.67	9.89	10.67	13.45	10.68	16.21	10.55	17.09
T_{11}	5.21	5.38	7.33	8.02	8.00	9.56	10.00	12.54	11.46	15.21	11.49	19.19
T_{12}	5.33	5.56	7.00	8.04	8.00	10.06	10.67	14.53	11.82	17.56	11.70	20.00
T_{13}	7.00	7.02	7.67	7.89	10.33	11.05	12.67	14.38	13.33	17.21	10.93	15.02

(Contd…)

Treatments	Number of leaves of okra cultivars (Mean of three replications)											
	Fortnightly interval after inoculation											
	1		2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C	I	C
T_{14}	7.00	7.06	7.67	7.98	10.67	11.56	12.33	14.25	14.33	17.06	11.80	15.11
T_{15}	5.33	5.55	7.00	7.45	8.67	9.56	11.67	13.65	13.00	16.21	13.57	19.23
T_{16}	5.00	5.09	6.67	7.02	8.00	8.78	10.67	11.89	12.33	16.52	13.42	19.00
T_{17}	7.00	7.12	7.00	7.35	8.67	9.56	9.67	10.89	10.59	14.56	14.00	21.52
T_{18}	5.33	6.23	6.00	7.86	9.00	13.06	11.00	18.95	15.33	28.54	9.23	31.02
T_{19}	5.64	6.00	7.00	7.56	9.33	10.56	13.67	15.98	14.49	18.63	14.33	21.45
T_{20}	6.33	7.00	6.67	8.00	9.67	13.56	11.67	17.24	15.00	20.56	12.68	18.35
T_{21}	6.33	6.56	6.33	7.06	9.00	11.56	12.00	16.59	11.66	19.02	11.76	22.06
T_{22}	5.08	5.12	7.67	7.86	10.33	11.01	10.67	11.56	12.33	15.06	12.38	15.26
T_{23}	5.67	6.12	7.67	9.04	8.33	11.23	11.00	18.29	12.33	22.56	9.02	27.20
T_{24}	5.20	5.38	6.00	6.45	8.00	9.05	9.67	11.56	10.33	14.25	10.34	17.21
T_{25}	5.67	6.00	6.67	7.32	8.00	9.41	9.33	11.98	10.33	16.23	10.35	21.52
T_{26}	5.42	5.52	7.00	7.45	7.67	8.99	9.00	11.56	10.33	16.32	10.38	20.36
T_{27}	5.33	5.57	7.33	7.98	7.67	8.56	9.67	11.85	11.00	16.54	11.21	18.42
T_{28}	5.33	5.45	7.33	8.23	8.00	9.79	8.67	11.63	9.00	15.65	9.34	17.52
T_{29}	5.30	5.65	6.00	7.23	7.00	9.16	7.67	10.98	8.66	13.52	8.71	16.00
T_{30}	5.33	5.65	6.33	6.99	7.67	8.68	8.67	10.56	14.33	17.89	12.76	20.23

*C -Control plant   I- Inoculated plant

Annexure III

Number of flowers of okra cultivars

Treatments	Number of flowers of okra cultivars (Mean of three replications) — Fortnightly interval after inoculation									
	2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C
T_1	1.21	1.23	1.31	1.39	3.33	4.32	3.37	4.82	3.58	6.67
T_2	1.33	1.33	1.72	1.87	2.63	3.45	3.38	4.67	3.51	5.59
T_3	1.31	1.33	2.49	2.78	2.22	3.00	2.77	3.91	3.33	5.67
T_4	1.30	1.32	1.85	1.95	2.87	3.33	2.39	3.04	3.67	5.20
T_5	1.23	1.31	1.64	1.89	2.67	3.85	2.67	3.82	2.37	4.23
T_6	1.00	1.00	2.72	2.79	1.50	1.57	2.11	2.37	2.52	3.14
T_7	1.21	1.25	2.16	2.45	1.81	2.08	2.88	3.71	4.52	6.00
T_8	1.11	1.11	1.41	1.50	2.40	2.74	2.87	3.53	3.98	6.68
T_9	1.31	1.33	1.78	1.95	2.34	3.08	2.45	3.10	3.09	5.45
T_{10}	1.29	1.37	2.11	2.33	2.06	2.45	2.26	2.99	3.56	5.99
T_{11}	1.17	1.17	1.29	1.39	2.68	3.09	2.89	3.54	3.74	5.00
T_{12}	1.06	1.12	2.15	2.42	1.74	2.27	1.82	2.53	3.33	5.76
T_{13}	1.19	1.19	2.29	2.29	2.46	2.57	2.67	2.89	3.67	4.52
T_{14}	1.30	1.35	2.06	2.22	2.00	2.22	3.08	3.73	4.13	5.10

(Contd ….)

Treatments	Number of flowers of okra cultivars (Mean of three replications)									
	Fortnightly interval after inoculation									
	2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C
T_{15}	1.19	1.20	1.45	1.65	2.11	2.61	2.30	3.03	3.67	5.89
T_{16}	1.49	1.52	1.52	1.85	1.55	2.11	2.77	3.70	3.35	4.95
T_{17}	1.19	1.20	1.75	2.11	2.18	2.71	2.88	3.58	3.67	4.66
T_{18}	0.00	0.00	2.45	2.96	1.91	2.96	1.96	3.18	3.59	6.92
T_{19}	1.34	1.39	1.34	1.56	2.74	3.32	2.90	3.63	3.09	4.23
T_{20}	1.35	1.39	1.75	1.95	2.90	3.70	2.90	3.90	3.56	5.29
T_{21}	1.46	1.48	2.51	2.75	2.55	3.10	2.00	2.73	3.33	5.00
T_{22}	1.56	1.56	1.52	1.53	2.22	2.29	2.31	2.47	4.33	5.21
T_{23}	1.78	1.86	1.85	2.22	2.11	2.96	2.80	4.04	3.19	5.82
T_{24}	1.60	1.65	1.58	1.89	2.31	2.76	2.57	3.48	3.67	5.33
T_{25}	1.50	1.57	1.48	1.56	2.00	2.25	2.75	3.42	3.67	4.78
T_{26}	1.60	1.65	1.45	1.55	2.18	2.71	2.50	3.13	3.32	4.33
T_{27}	1.19	1.20	1.25	1.35	3.51	4.70	2.17	3.07	2.82	4.67
T_{28}	1.80	1.88	1.42	1.62	1.78	2.74	2.60	4.14	2.94	5.66
T_{29}	1.20	1.26	1.23	1.42	2.72	4.15	2.40	3.80	3.15	5.91
T_{30}	1.12	1.18	1.39	1.67	2.08	2.88	2.27	3.23	3.19	5.77

*Flowering of okra plants not initiated at first fortnightly interval after inoculation

*C-Control I-Inoculated

Annexure IV

Number of fruits of okra cultivars

Treatments	Number of fruits of okra cultivars (Mean of three replications)									
	Fortnightly interval after inoculation									
	2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C
T_1	1.21	1.23	1.25	1.33	2.00	2.67	1.88	3.19	2.67	5.00
T_2	1.33	1.33	1.69	1.82	1.64	2.42	2.00	3.12	2.79	4.67
T_3	1.31	1.33	2.12	2.33	1.85	2.52	1.85	2.83	2.55	4.60
T_4	1.16	1.18	1.21	1.45	1.31	2.00	1.72	3.00	2.48	4.67
T_5	1.00	1.06	1.26	1.46	1.98	3.02	1.00	1.67	1.77	3.13
T_6	1.00	1.00	2.33	2.33	1.42	1.52	2.00	2.33	1.62	2.00
T_7	1.21	1.25	1.85	2.12	1.59	1.89	2.16	2.85	2.49	3.55
T_8	1.00	1.00	1.26	1.33	1.69	2.43	1.67	2.68	2.67	4.67
T_9	1.23	1.26	1.56	1.68	1.65	2.33	1.33	2.33	2.33	3.67
T_{10}	1.00	1.02	1.52	1.57	1.65	2.30	1.76	2.68	2.33	4.00
T_{11}	1.00	1.00	1.12	1.21	2.45	3.00	2.33	3.33	2.11	3.45
T_{12}	1.06	1.12	2.00	2.33	1.25	1.72	1.33	2.13	1.33	2.47
T_{13}	1.00	1.00	2.29	2.29	2.45	2.66	2.33	2.67	2.15	2.67
T_{14}	1.21	1.21	1.28	1.33	1.19	1.33	1.33	1.66	3.12	4.20

(Contd…)

Treatments	Number of fruits of okra cultivars (Mean of three replications) Fortnightly interval after inoculation									
	2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C
T_{15}	1.12	1.14	1.25	1.45	1.98	2.76	1.85	2.78	2.33	4.00
T_{16}	1.41	1.45	1.52	1.85	1.52	2.00	1.82	2.74	2.15	3.27
T_{17}	1.19	1.20	1.65	2.01	2.11	2.67	1.75	2.33	2.48	4.00
T_{18}	0.00	0.00	1.00	1.20	1.72	2.71	1.67	3.00	2.11	4.20
T_{19}	1.29	1.32	1.34	1.56	2.10	2.52	1.67	2.33	3.00	4.73
T_{20}	1.30	1.33	1.65	1.87	1.67	2.36	2.00	3.37	2.58	4.67
T_{21}	1.00	1.04	2.47	2.67	1.55	2.22	1.74	2.75	2.33	4.19
T_{22}	1.00	1.00	1.02	1.02	3.45	3.67	2.67	3.00	2.45	3.00
T_{23}	1.10	1.12	1.78	2.14	2.10	3.25	1.45	2.60	2.00	3.98
T_{24}	1.25	1.29	1.52	1.89	1.56	2.33	1.59	2.62	2.40	4.37
T_{25}	1.08	1.11	1.38	1.46	1.92	2.25	1.62	2.00	2.00	3.00
T_{26}	1.29	1.33	1.25	1.33	1.66	2.01	1.67	2.33	2.34	3.53
T_{27}	1.00	1.00	1.19	1.25	1.62	2.45	1.70	2.67	2.33	3.84
T_{28}	1.19	1.23	1.85	1.95	1.86	2.31	2.33	3.00	2.00	3.19
T_{29}	1.20	1.26	1.01	1.24	1.11	1.65	1.33	2.21	1.86	3.36
T_{30}	1.03	1.09	1.39	1.67	1.19	1.73	1.75	2.76	2.00	3.67

*Fruiting of okra plants not initiated at first fortnightly interval after inoculation

*C-Control I-Inoculated

Annexure V

Fruit weight of the okra cultivars

Treatments	Fruit weight of okra cultivars (Mean of three replications)									
	Fortnightly interval after inoculation									
	2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C
T_1	15.30	15.41	15.30	15.46	15.37	15.80	13.20	13.90	13.17	14.20
T_2	15.23	15.34	15.37	15.64	15.33	15.65	13.53	14.23	13.50	14.24
T_3	13.42	13.60	13.47	13.61	13.33	13.58	12.60	13.00	12.47	13.21
T_4	15.52	15.77	15.30	15.68	15.29	15.84	13.59	14.62	13.21	14.87
T_5	14.53	14.62	14.53	14.78	14.54	14.98	13.47	14.23	13.30	14.36
T_6	14.57	14.63	14.57	14.68	14.50	14.68	13.87	14.10	13.63	14.02
T_7	14.57	14.61	14.50	14.75	14.37	14.55	13.57	14.00	13.43	14.20
T_8	15.27	15.40	15.40	15.60	15.30	15.52	13.53	13.98	13.37	13.99
T_9	16.33	16.52	16.33	16.50	16.47	16.70	15.57	15.80	15.40	15.98
T_{10}	16.27	16.45	16.51	16.72	16.40	16.78	16.17	16.86	15.57	16.52
T_{11}	16.37	16.45	15.33	15.55	16.50	16.79	14.37	15.20	14.70	15.21
T_{12}	15.44	15.60	15.40	15.65	15.63	15.98	15.50	16.00	15.37	16.20
T_{13}	14.57	14.60	14.57	14.69	14.60	14.78	13.93	14.12	13.84	14.12
T_{14}	13.87	13.90	13.57	13.75	13.87	13.98	12.33	12.48	11.87	12.10

Contd…

Treatments	Fruit weight of okra cultivars (Mean of three replications) Fortnightly interval after inoculation									
	2		3		4		5		6	
	I	C	I	C	I	C	I	C	I	C
T_{15}	13.47	13.67	13.26	13.50	13.11	13.39	13.00	13.25	12.80	13.20
T_{16}	16.27	16.35	16.30	16.40	16.30	16.56	16.47	16.98	16.13	16.98
T_{17}	15.23	15.32	15.23	15.42	15.22	15.46	15.47	15.82	15.23	15.72
T_{18}	0.00	0.00	21.23	21.45	21.21	21.90	20.44	21.75	19.81	21.61
T_{19}	16.30	16.45	16.30	16.60	16.40	16.90	15.90	16.52	15.80	16.52
T_{20}	15.57	15.72	15.43	15.70	15.63	15.98	15.60	15.98	15.03	15.65
T_{21}	14.93	14.96	14.83	14.96	14.53	14.90	13.90	14.56	13.40	14.26
T_{22}	19.40	19.50	19.40	19.49	19.23	19.33	18.00	18.21	17.90	18.21
T_{23}	15.30	15.46	15.37	15.60	15.52	15.90	15.07	16.08	14.73	16.06
T_{24}	16.30	16.50	16.27	16.49	16.00	16.50	15.03	16.00	14.97	16.36
T_{25}	17.20	17.40	17.20	17.40	17.03	17.46	15.10	16.00	14.07	15.00
T_{26}	16.43	16.58	16.43	16.69	16.70	17.20	15.17	16.06	14.77	16.00
T_{27}	15.70	15.94	15.55	15.88	15.83	16.35	15.11	16.31	14.63	16.30
T_{28}	16.71	16.82	16.26	16.45	16.93	17.32	16.17	16.89	15.07	16.00
T_{29}	19.03	19.16	19.10	19.30	19.23	19.53	18.33	19.00	18.27	19.20
T_{30}	15.40	15.50	15.30	15.53	15.37	15.65	14.67	15.20	14.60	15.30

* Fruiting of okra plants not initiated at first fortnightly interval after inoculation

*C-Control I-Inoculated

RESPONSE OF SELECTED OKRA [*Abelmoschus esculentus* (L.) Moench] CULTIVARS TO ROOT KNOT NEMATODE *Meloidogyne incognita* (Kofoid and White)

By

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ABSTRACT OF THE THESIS

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160

Abstract

Okra [*Abelmoschus esculentus* (L.) Moench] is an important vegetable crop, popularly known as "bhendi" or "lady's finger" in India. It is grown in three seasons in the tropical and subtropical regions throughout the world. The nutritional, medicinal and industrial value of okra fruits makes it a promising vegetable crop globally.

Pests and diseases are the major limiting factors for okra cultivation. Among them plant parasitic nematodes are the most serious. Root-knot nematode, *Meloidogyne incognita* is one of the most economically damaging genera of plant parasitic nematodes which causes 31 per cent of yield loss in India (Jain *et al*., 2006). Several methods have been developed for the management of the nematode. Use of chemical nematicides is the most effective, which brings about 80 per cent reduction in nematode population. Host resistance is an important component of integrated nematode management. Use of cultivars resistant to *M. incognita* is one of the best alternatives, which is specific, environmentally safe and economically feasible.

In this context, a study entitled "Response of selected okra [*Abelmoschus esculentus* (L.) Moench] cultivars to root knot nematode, *Meloidogyne incognita* (Kofoid and White)" was carried out in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during January 2016 to October 2016, with the objective of screening selected okra cultivars against *M. incognita* and to elucidate the biochemical basis of resistance.

Thirty okra cultivars comprising twenty one accessions from NBPGR Regional Station, Thrissur, eight released varieties and a highly susceptible check (Arka Anamika) were screened for their reaction to root knot nematode *M.incognita.*

Pot culture experiment was conducted in Completely Randomized Design with three replications and 30 treatments. Okra plants were inoculated with *M.incognita* @ one second stage juvenile per gram of soil after two weeks of seed germination. Biometric characters like plant height, number of leaves, number of flowers, number of fruits and fruit weight were recorded at fortnightly intervals from the time of inoculation till uprooting. Shoot weight, root weight, root knot number and nematode population in soil and roots were also recorded when the plants were uprooted *i.e.* three months after inoculation.

Significant reductions in all the biometric parameters were observed over their respective controls in all the cultivars. The per cent decrease in these parameters were higher in highly susceptible and susceptible cultivars than moderately resistant cultivars.

Based on the number of galls per 10 g roots, indexing was done on 1-5 scale and the okra cultivars were categorized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible (Devi *et al.,* 2014). None of the cultivars were highly resistant or resistant whereas four cultivars *viz.,* IC 117238, IC 117251, IC 111507 and Varsha Uphar with root knot index 3 were classified as moderately resistant. Seven cultivars *viz.,* Manjima, IC 111536, IC 117260, IC 111500, IC 111247, IC 469689 and IC 111517 were found to be susceptible with root knot index 4. Rest of the nineteen cultivars *viz.,* Aruna, Kiran, Anjitha, Salkeerthi, Susthira, Arka Anamika, Pusa Sawani, IC 218900, IC 112457, IC 329360, IC 045819, IC 117308, IC 117228, IC 111525, IC 111514, IC 329357, IC 282275, IC 305634 and IC 045515 were classified as highly susceptible with root knot index 5.

Biochemical parameters like total phenol, peroxidase (PO), total sugar and reducing sugar of both control and inoculated roots of okra cultivars were estimated at three months after inoculation based on standard procedures to analyze the biochemical bases of resistance.

An increase in total phenol and peroxidase activity was noticed in moderately resistant cultivars than susceptible cultivars whereas total sugar and reducing sugars were higher in highly susceptible cultivars. Correlation analysis showed a significant negative correlation between total phenol content and peroxidase activity with number of root knots, root knot index and population of *M. incognita* in root and soil. A significant positive correlation of total sugar and reducing sugar was recorded with number of root knots, root knot index and population of *M. incognita* in root and soil.

The present study revealed that IC 117238, IC 117251, IC 111507 and Varsha Uphar were moderately resistant. Hence these cultivars could be utilized as resistant sources for further breeding programmes. Field trials in sick plots also need to be conducted to study the field performance of the moderately resistant cultivars.