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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
A. P. CESS FUND SCHEME

Interactions between Vesicular Arbuscular Mycorrhizae (VAM) and Burrowing Nematode on Coconut

FINAL REPORT
1988–'93

SOSAMMA VARGHESE, K.
PRINCIPAL INVESTIGATOR

DIVISION OF PLANT PROTECTION
Central Plantation Crops Research Institute
REGIONAL STATION, KAYANGULAM
KRISHNAPURAM – 690 533, KERALA

FINAL REPORT OF RESEARCH SCHEME

1. Project Title : "Interaction between Vesicular Arbuscular Mycorrhizae (VAM) and burrowing nematode on coconut".
2. Sanction No. : F.No. 1-30/84 pp dt 28-3-1988
3. Date of start : 5-9-1988
4. Date of termination : 4-9-1993
5. (a) Name of Institute : Central Plantation Crops Research Institute
   (b) Division : Plant Protection
   (c) Location of work : Nematology Laboratory, CPCRI (RS), Kayangulum
6. (a) Research Scientist associated : Dr. P.K. Koshy, Principal Scientist
   (b) Technical personnel employed :

Name with designation	Date of joining	Date of leaving	Total No.of man months spent
Sobha.A. Thottungal, Senior Research Fellow	5- 9-1988	1-4-1991	31
Rachel Samuel, Research Associate	16- 1-1989	4-9-1993	57
Bindu.S.Menon, Senior Research Fellow	18-11-1991	4-9-1993	23

7. Total outlay :

Share of ICAR	Share of participating agency
Rs. 3,68,134	Nil

8. Total amount spent :

Rs. 3,68,116	Nil

9. Objectives and how far these have been achieved :

All the objectives of the scheme have been achieved.

1. To study the occurrence of VAM on Coconut and to study its interaction with burrowing nematode in order to explore the possibilities of using VAM inoculation as protective measure against nematode attack both in nurseries and in planting pits.

Survey carried out in six different districts of Kerala confirmed the natural association of VA mycorrhizae with Coconut. Resting spores of VAM recovered from different soil types viz. alluvial, clayey, forest, Kari, laterite, sandy and loamy sand soil proved the omnipresence of VAM in the coconut rhizosphere. The resting spores of twenty one VAM species viz. Acaulospora bireticulata, A. laevis, A. trappei, Gigaspora aurigloba, G. coralloidea, G. gilmorei, G. margarita, G. nigra, G. pellucida, Glomus fasciculatum, G. fuegianum, G. invermaium, G. macrocarpum, G. microcarpum, G. mosseae, G. pallidum, Sclerocystis clavispora, S. coremioides, S. microcarpum, S. rubiformis and S. sinuosa were

identified from the soil around the roots of coconut palms. Apart from these, four more species were encountered which could not be identified. Attempts are being made to identify them to species level. Percentage root infection varied from 0-100 per cent.

VAM (Glomus mosseae) inoculation in coconut (West Coast Tall) nursery enhanced vegetative growth in terms of height and leaf area. With increase in the quantum of inoculum/ number of inoculations there was a corresponding increase in the height and leaf area of the seedlings where as the number of leaves remained same. With increase in inoculum density there was corresponding increase in the leaf area of the seedlings but increase in number of leaves was not significant.

2. To study the effect of various nematicide treatments on the successful colonisation of VAM on coconut.

Among the three different nematicides tested against VAM viz. Carbofuran, Ebufos and Phorate, Phorate proved to be the best nematicide with least deleterious effect on VA mycorrhizal colonisation on coconut palms.

10. Approved Technical Programme

1. Collection and identification of VA mycorrhizae on coconut from various soil types and different varieties in Kerala and mass multiplication on primary host and other graminaceous hosts.

2. Interaction studies of burrowing nematode and VA mycorrhizae

on coconut.

3. Screening of nematicides to find out an effective nemati - cide with least deleterious effect on VA mycorrhizae.
4. Studies on population build up of VA mycorrhizae and burrowing nematode under field conditions in high density multispecies cropping systems including coconut by introduction of mycorrhizal plants.
5. Studies on standardisation of mode, time and frequency of inoculation and quantum of inoculum in nursery and planting pits.

a) Remarks of Scientific Panel on earlier Annual Report :

Report accepted.

11. Detailed Report

1. Standardisation of sampling zone/area for VA mycorrhizal estimation

Five coconut palms in different Blocks of the farm at the Central Plantation Crops Research Institute, Kayangulam, Kerala were selected. Soil samples were collected from each coconut palm basin from three different points at various distances viz. 50, 75, 100, 150 and 200 cm away from the bole of the palm. At each distance samples were taken from different depths viz. 0-25, 26-50, 51-75 and 76-100 cm (20 samples/palm/month). Soil collected at each depth was mixed well and an aliquot of 50 g soil was taken. This 50 g soil was mixed well, evenly suspended in water and then passed

through sieves of 60 (710μ), 150 (105μ), 200 (75μ) and 350 (45μ) meshes. The catch on each sieve was collected and made upto 100 ml suspension in a beaker. This suspension was stirred well by bubbling air through a pipette and 2ml from this suspension was pipetted out into a Doncaster counting dish and observed under a binocular stereo microscope. Observation of the 2 ml suspension was repeated three times to minimise the error during observation and average of three observations were recorded. The resting spores present in the sievings (soil sample) were then identified using Trappe's Synoptic Key (1982). Maximum VA mycorrhizal resting spores could be recovered at a distance of 100 cm away from the bole of the palm within a depth of 26-100 cm (Table 1). Maximum resting spores were obtained from 150 mesh followed by 200 mesh sievings (Table 2).

2. Recovery of VA mycorrhizal resting spores from the soil

Soil sample was collected at a distance of one metre away from the bole of the palm, to a depth of 25-100 cm, from three angles in the coconut basin using 2" diametre iron pipe. This soil was mixed well and an aliquot of 50 g from this was taken. This soil was evenly suspended in water and then passed first through 20 mesh sieve (840μ) to remove roots and bigger soil particles and then through 150 (105μ) and 200 (75μ) meshes. The sievings of the 150 and 200 mesh yielded maximum resting spores. Therefore, for all experiments resting spores in sievings of 150 and

Table 1

VAM resting spores recovered at different depths and distances

(Average of 5 coconut palms)

Depth (cm)	Distance from the bole of the palm				
	50 cm	75 cm	100 cm	150 cm	200 cm
0- 25	45	60	62	31	31
26- 50	41	70	121	44	24
51-75	62	107	125	71	35
76-100	78	86	119	64	24

Table 2

Number of VAM resting spores recovered from different sieves

(Average of 100 samples)

Sieve		No. of spores
Mesh No.	Pore size (μ)	
60	250	4
150	105	24
200	75	29
350	45	4

200 mesh were counted.

3. Standardisation of type of root

Main, secondary and tertiary roots of coconut (15year old) palm grown in sandy loam soil in CPCRI, Farm, Kayangulam, were collected, washed free of soil and cut into 1 cm bits. These roots were stained in Trypan blue using standard staining technique for mycorrhizal estimation. All types of roots (main, secondary and tertiary) of coconut recorded VAM colonisation (Table 3). Maximum colonisation was noticed in the fine yellowish brown to light brown tertiary roots of coconut (0-100%) followed by 50 and 40 per cent in secondary and primary roots respectively (Table 4). Colonisation was less in hard reddish brown to dark brown roots (Primary, Secondary and Tertiary) compared to tender yellowish brown to light brown coloured roots (Table 5). The root cap region of any tender growing root was found to be free of mycelial growth of mycorrhizae.

4. Estimation of VA mycorrhizal colonisation in roots

The methods of Philips and Hayman (1970) and Koske and Jamma (1989) were tried for the detection of VA mycorrhizae in coconut roots. Both methods gave satisfactory results. However, the method was modified (Table 6) for easy handling of large number of samples as follows: Coconut roots-tertiary and primary, collected from each sample were washed and cut into one centimeter bits.

Table 3

Type of coconut root showing maximum VAM colonisation

Type of root	Total No. of root bits examined	Presence of		Root infection (%)
		Hyphae & Arbuscules	Hyphae, Arbuscules & Vesicles	
Feeder roots (Tertiary)				
Tender creamy (1 mm thick)	100	40	40	80
Semi hard yellow to brown (1mm thick)	100	70	30	100
Tender creamy (3-4 mm)	100	10	-	10
Hard light brown (3-4 mm)	100	20	-	20
Lateral roots (Secondary)				
Light brown hard (6-7 mm)	100	50	-	50
Primary roots (Main)				
Brown hard (6-7 mm)	100	40	-	40

Table 4

VA mycorrhizal colonisation in different types of coconut root

Type of root	VA mycorrhizal Infection (%)
Fine feeder	0-100
Secondary	0- 50
Primary	0- 40

Table 5

VA mycorrhizal colonisation in different types of coconut roots

Type of root	Root infection (%)			
	* A	B	C	D
Tertiary	0-10	0-100	0-40	0-12
Secondary	0-10	0- 50	0-40	0-20
Main	0-10	0- 40	0	0

A - Creamy white

B - Yellowish to light orange

C - Orange to light brown

D - Dark brown

Table 6

Process for the estimation of VA mycorrhizal infection in roots

Wash the roots

↓

cut into 1 cm bits

↓

Heat in 2.5 % KOH for 3 min

or

leave overnight in KOH

↓

Wash in H_2O

↓

Bleach in alkaline H_2O_2

↓

Wash in H_2O

↓

Acidify by soaking in 1 % HCl (20-50 vol)

for 1 - 24 hrs.

↓

Stain with Trypan blue in acidic glycerol

Later these roots were heated in 2.5 per cent Potassium hydroxide (KOH) for 3 minutes for quick observation or left overnight under laboratory condition (28 -32°C) for later observations. The roots were washed in water, bleached in alkaline H_2O_2, rinsed again in water and acidified by soaking in one per cent HCl (20-50 Vol) for 1-24 hours depending upon the hardness of the roots. Perfect acidification of the root is very essential for proper staining. Then the roots are stained with Trypan blue in acidic glycerol (0.05 per cent Trypan blue in a mixture of 500 ml glycerol, 450 ml water and 50 ml one per cent HCl). Destaining in acidic glycerol can remove excess stain. For all experiments this method was followed.

5. Soil sterilisation

The loamy sand soil used for the raising up of mycorrhizal seedlings for all experiments was steam sterilised in an autoclave under 20 pounds pressure for one hour on two alternate days and stored in sterile cement tubs covered with polythene sheets.

6. Raising up of experimental coconut seedlings

The nuts from three elite WCT coconut mother palms were used for the raising up of experimental seedlings. The dehusked nuts retaining tufts of hairs (mesocarp) above the fertile eye were sown in steam sterilised soil and kept in the greenhouse (Koshy and Sosamma 1982). The experimental seedlings and culture pots were watered daily using only boiled and cooled water.

7. Mass multiplication and maintenance of cultures

a. Vesicular Arbuscular Mycorrhizae (VAM)

Resting spores of Acaulospora bireticulata Rothw and and Trappe., Glomus fasciculatum (Thaxter sensu Gerd.) Gerd. and Trappe., Glomus macrocarpum Tul. and Tul., Glomus mosseae (Nicol. and Gerd.) Gerd. and Trappe., Glomus versiforme (Karst.) Berch., Gigaspora nigra Redhead in Nicol. and Schenck., Gigaspora pellucida Nicol. and Schenck., Sclerocystis coremioides Bk. and Br. and Sclerocystis rubiformis Gerd. and Trappe isolated from local elite coconut palms are mass multiplied and maintained on coconut and sorghum in culture pots in steam sterilised soil in the greenhouse and under open field conditions.

b. Radopholus similis

The coconut isolate of the burrowing nematode, Radopholus similis (Cobb, 1893) Thorne 1949 is being mass multiplied and maintained on coconut seedlings grown in large cement tubs containing sandy loam soil fumigated with Methyl bromide @ 500g/2.83 m^2 for 72 h under polythene cover and also axenically on carrot discs in the laboratory at a temperature range of 20 - 24°C.

8. Estimation of nematode population in the soil and root

Soil samples were collected at a distance of 1 metre away from the bole of the palm to a depth of 25-100 cm from three different loci in the basin. This soil was mixed well and an aliquot of 250g was taken and processed

according to Cobb's sieving and sifting method. The nematode population was assessed under a stereoscopic microscope. A sample of 50 g tender creamy white fleshy main roots were also collected for estimating the nematode population in the roots. The roots were cut into one inch (2.5-3 cm) long bits and split longitudinally into 4-8 pieces. The split root bits were left in water in petri plates at a temperature of 14 to 20°C in a refrigerator or BOD for 72 hours for the extraction of nematodes (Koshy et al., 1975). The nematodes were separated after passing the suspension through 20 (840/μm) to remove the root pieces and then through 60 (250/μm) and finally through 400 mesh (38/μm) sieve. The sieving was washed into a 150 ml beaker for observation and counting. This method was followed in all experiments. Active R. similis population, required for inoculation, culturing etc was collected as per the following procedure: The nematode suspension extracted from roots, was poured on to two layers of face tissue papers placed on a moulded aluminium wire gauze and then placed on a petridish (10 cm dia) with sufficient water to keep the samples wet for 24 hours. The nematode suspension from petridish was transferred to a 100 ml beaker for settling and decanting. Active R. similis specimens (females and larvae) were separated

out by hand picking individually under a stereoscopic binocular dissection microscope to sterile water.

Axenic culturing

Fresh, good quality (uninjured) carrot tubers were selected and washed thoroughly under running tap water. The tubers were drained free of water and then transferred into a laminar flow clean air bench. The tubers were then dipped individually in 95 per cent ethanol, flamed, pared off all epidermis, using a sterile blade, cut into uniform discs. Each disc was then introduced into a 100 ml Erlenmeyer conical flask containing 40 ml of one per cent sterile water agar and left under laboratory conditions for 3-7 days to observe for contamination if any, and for initiation of callus growth. The nematode population extracted from the infested coconut roots was pipetted into sterile centrifuge tubes and concentrated at 3000 rpm. The supernatent was decanted, added 0.1 % Mercuric chloride and again centrifuged for a minute. Again the supernatent was decanted and centrifuged with sterile water for 15 seconds twice. The supernatent was decanted and centrifuged for one minute using 0.1 per cent Streptomycin sulphate. The supernatent was decanted and the nematode suspension was drawn into a sterile syringe and introduced on to carrot discs in a laminar flow clean air bench. The inoculated culture flasks were maintained at a temperature of 20 $\pm$ 1°C in a B.O.D incubator.

10. Assessment of endomycorrhizal infection in different coconut varieties/cultivars

Root samples from 28 cultivar/hybrid palms grown in CPCRI Farm, were drawn and processed for estimating the VA mycorrhizal infection. The per cent infection varied from palm to palm in different cultivars/hybrids (Table 7). VAM colonisation was seen in the roots of all hybrids/ cultivars and percentage infection ranged from 30-100.

11. Selection of VAM for experimental studies

The endomycorrhizal cultures viz. Glomus fasciculatum, G. mosseae and G. versiforme were inoculated on to coconut seedlings (WCT) to estimate the per cent infection and host suitability. Coconut seedlings were raised up in steam sterilised soil in 35 cm earthen pots in the green-house. The endomycorrhizal inoculum of respective culture consisted of 100 g soil + root from the culture pots (900 spores/50 g soil). The inoculation was carried out after exposing the roots by removing the soil around the roots and then the inoculum was applied on to the tender white fibrous roots in order to ensure proximity of spores to the growing roots. After three months, the experimental plants were sampled and the mycorrhizal infection in the roots were estimated. Results showed that maximum per cent infection was noticed in G. mosseae (66 %) followed by G. fasiculatum (60 %) and G. versi-forme (46 %).

Table 7

VA mycorrhizal colonisation in different Coconut cultivars / Hybrids

S. No.	Cultivar / Hybrid	Maximum percentage infection
1.	Benaulim	100
2.	Carnicobar	"
3.	East Coast Tall	"
4.	Guam	"
5.	Java	"
6.	Java Giant	"
7.	Kenthali	"
8.	Kenya	"
9.	Laccadive Dwarf	"
10.	Lifou Tall	"
11.	Laccadive Micro	"
12.	Malayan Dwarf Green	"
13.	Malayan Dwarf Orange	"
14.	Malayan Dwarf Yellow	"
15.	MAWA	"
16.	Orissa Tall	"
17.	Rangoon Kobari	"
18.	S.S Apricot	"
19.	Verri Kobari	"
20.	West Coast Tall	"
21.	Laccadive Ordinary	90
22.	Tiptur Tall	"
23.	Dwarf Orange	"
24.	Markham Tall	80
25.	Dwarf Green	"
26.	D x T	"
27.	Tall x Gangabondam	70
28.	Spicata	"

2. Collection and identification of VAM in different soil types

Soil and root samples of 279 coconut palms growing in different soil types viz. Alluvial, Clayey, Forest, Kari, Laterite, Sandy and Sandy loam from the Alleppey, Idukki, Kottayam, Pathanamthitta, Quilon and Trivandrum districts (Table 8) were collected. The soil and root samples were drawn from the rhizosphere of each coconut palm and processed separately for nematode and mycorrhizal estimation as described earlier. Table 9 gives the range of VAM infection recorded in the roots of coconut palms growing in different soil types.

The VA mycorrhizal spores identified to be associated with coconut palms are Acaulospora bireticulata Rothw. and Trappe., A. laevis Gerd. and Trappe., A. trappei Ames and Lind., Glomus fasciculatum (Thaxter sensu Gerd.)., G. fuegianum (Speg.) Trapne and Gerd., G. invermaium Hall., G. macrocarpum Tul. and Tul., G. microcarpum Tul. and Tul., G. pallidum Hall., G. mosseae (Nicol. and Gerd.) Gerd. and Trappe., Gigaspora aurigloba Hall., G. coralloidea Trappe., Gerd. and Ho., G. gilmorei Trappe and Gerd., G. margarita Becker and Hall., G. nigra Redhead in Nicol and Schenck., G. pellucida Nicol and Schenck., Sclerocystis clavispora Trappe., S. coremioides Bk. and Br., S. microcarpus Iqbal and Bushra., S. rubiformis Gerd. and Trappe., and S. sinuosa Gerd. and

Table 8

VA mycorrhizal association of coconut palms in different soil types

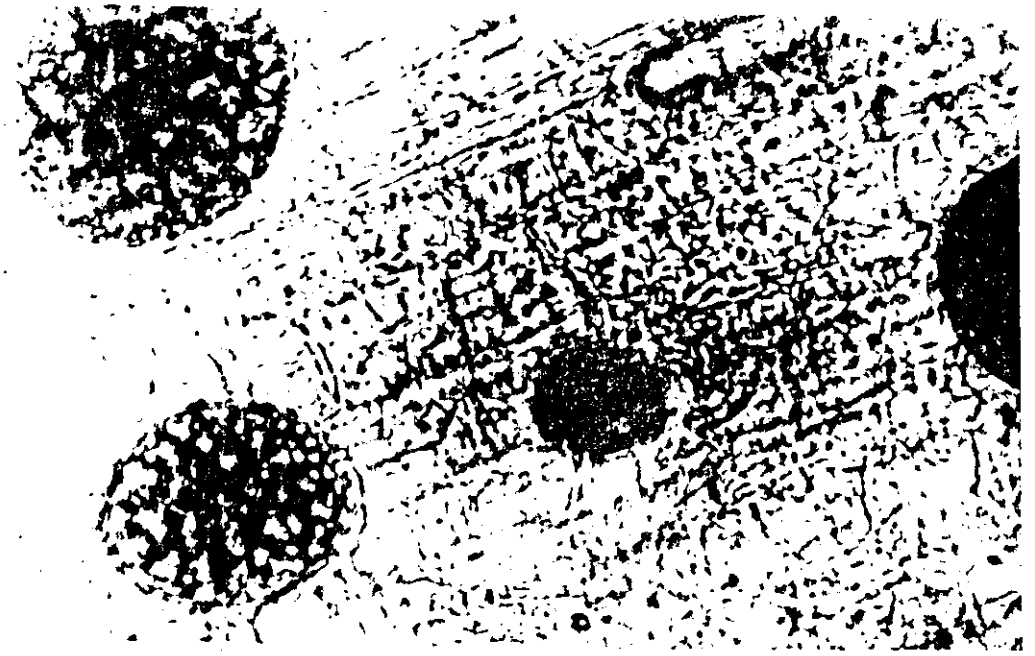
Soil type	Total number of palms screened	Number of palms with mycorrhizal infection	No. of palms with 100 per cent root infection
Alluvial	27	26	6
Clayey	7	7	0
Forest	1	1	1
Kari	2	1	0
Laterite	84	83	11
Sandy	27	27	3
Sandy loam	131	131	55
Total	279	276	76

Table 9

Range of VAM infection on coconut in different soil types

Soil type	Root infection (%)
Alluvial	0-100
Clayey	20- 60
Kari	0- 60
Laterite	0-100
Sandy	30-100
Sandy loam	20-100

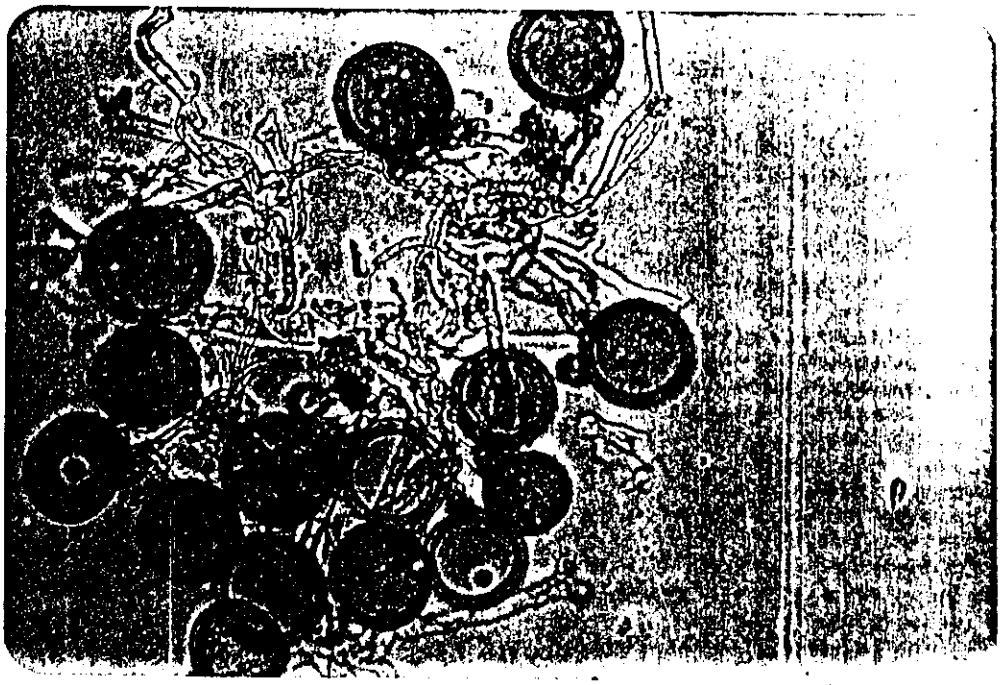
Plate I



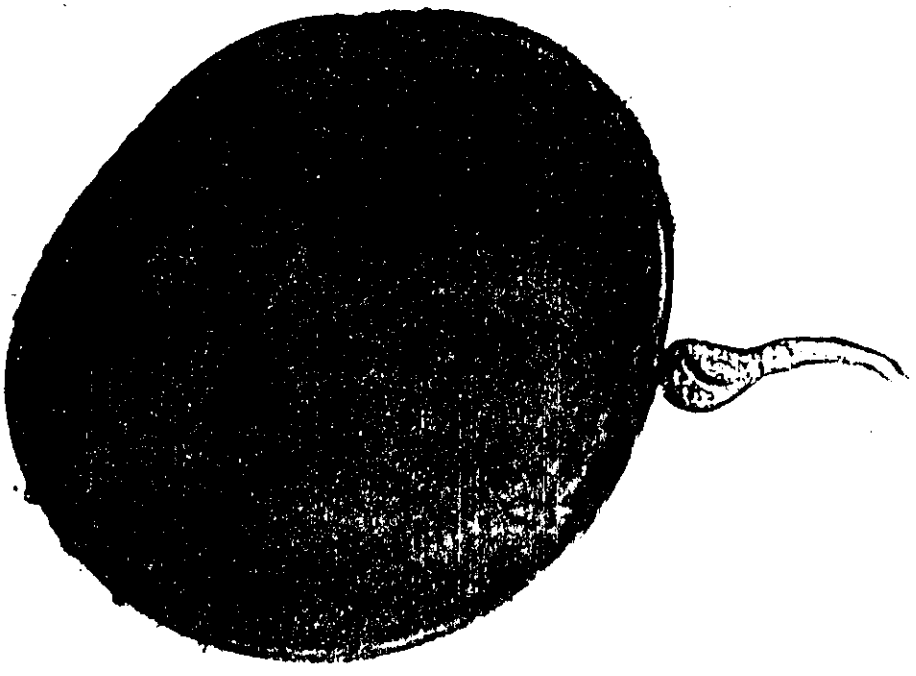
a. Acaulospora bireticulata
on coconut root

b. A. laevis - broken spore

Plate II



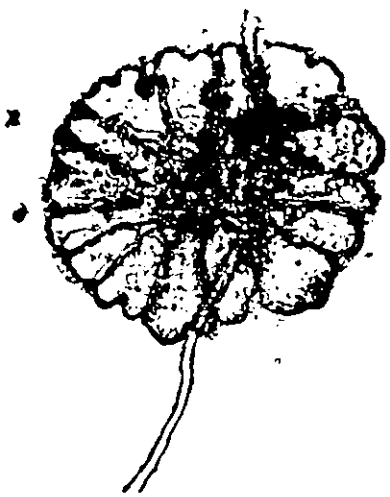
a. Glomus fasciculatum - sporocarp



b. Gigaspora coralloidea showing the bulbous hyphal attachment

Plate III

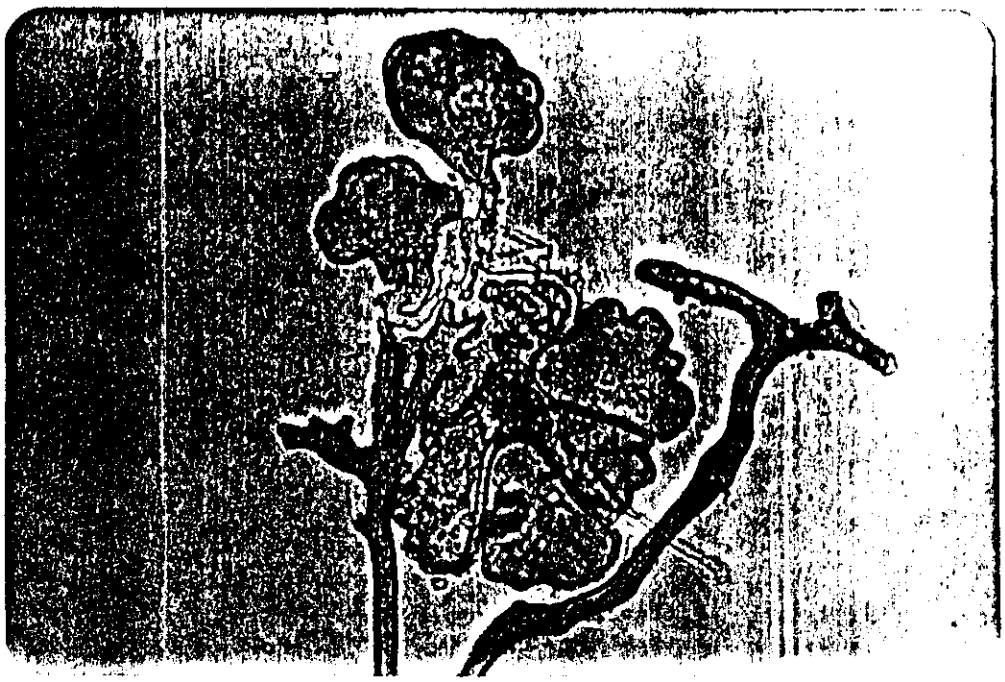
(a)



a & b - Accessory soil borne vesicles of Gigaspora sp.

(b)

Plate IV



a & b - Accessory soil borne vesicles of Gigaspora sp.

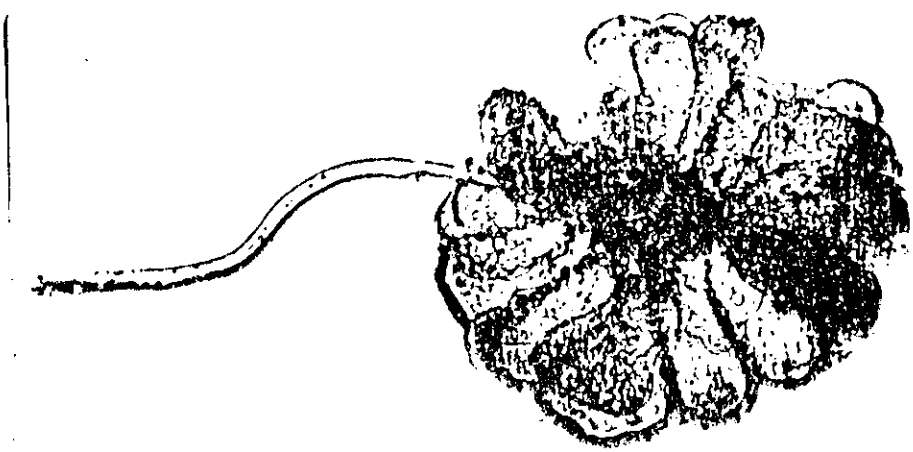


Plate V

a & b - Coconut root with external and internal hyphae, vesicles and spores of Glomus mosseae

Plate VI

a - Glomus macrocarpum on coconut root showing ramifying hyphae and spores

b - Hyphae and spores of G. macrocarpum on coconut root-enlarged

Bakshi (Table 10 and Plates I to VI). Apart from the above, four more species were also encountered. Which are yet to be identified. Attempts are being made to identify them to species level. The feeder root samples of most of the palms showed dense infection (80-100 per cent) with both internal and external hyphae, vesicles, arbuscules and spores. Resting spores recovered from the soil (in the coconut rhizosphere) varied from palm to palm. There was no direct co-relation between the percentage root infection and resting spore numbers in soil. Some of the palms with mycorrhizal root infection recorded no spores while even a maximum number of 1750 spores / 50 g of soil was also recorded from the survey. The nematodes found in the soil were Aphelenchus sp., Criconemoides sp., Dolichodorus sp., Ditylenchus sp., Ecphyadophora sp., Helicotylenchus abunaamai, Hoplolaimus seinhorsti, Longidorus saginus, Meloidogyne larvae, Pratylenchus zeae, Radopholus similis, Rotylenchulus reniformis, Trichodorus sp., Tylenchorhynchus sp., Tylenchus sp., and Xiphinema sp., (Table 11). R. similis was recorded in 26 palms where VAM infection ranged from 20 -100 per cent.

Identification of VAM from healthy and diseased coconut palms

Soil and root samples of healthy and root (wilt) affected coconut palms from different localities were collected and processed to assess the VA mycorrhizal and nematode

Table 10

VA mycorrhizal spores recovered from different soil types

Sl.No.	Spore type	Soil type						
		Alluvial	Clayey	Forest	Kari	Laterite	Sandy	Sandy loam
1.	Acaulospora bireticulata	*	*	*	*	*	*	*
2.	A. laevis	*	-	-	*	*	-	*
3.	A. trappei	-	-	-	-	*	*	*
4.	Glomus fasciculatum	*	*	*	*	*	*	*
5.	G. fuegianum	*	*	-	*	*	*	*
6.	G. invermaium	-	-	-	-	-	*	*
7.	G. macrocarpum	-	*	*	*	*	*	*
8.	G. microcarpum	-	-	-	*	-	-	-
9.	G. pallidum	-	-	-	-	-	*	-
10.	G. mosseae	*	*	-	*	*	*	*
11.	Gigaspora auriglobe	*	*	-	-	*	*	*
12.	G. coralloidea	*	*	*	*	*	*	*
13.	G. gilmorei	*	*	-	-	*	*	*
14.	G. margarita	*	-	-	*	*	-	*
15.	G. nigra	-	*	*	-	*	*	*
16.	G. pellucida	*	-	-	-	-	-	-
17.	Sclerocystis clavispora	*	-	-	-	*	*	*
18.	S. coremioides	*	*	*	*	*	*	*
19.	S. microcarpum	-	-	-	-	-	*	-
20.	S. rubiformis	*	*	*	*	*	*	*
21.	S. sinuosa	*	-	-	-	-	-	-

* present - absent

Table 11

Nematode genera encountered in different soil types

Nematode	Soil type					
	Alluvial 1	Clayey 2	Kari 3	Laterite 4	Sandy 5	Sandy loam 6
Aphelenchus	-	-	-	+	+	+
Criconemoides	+	+	-	+	+	+
Ditylenchus	-	-	-	-	+	-
Dolichodorus	-	-	-	+	+	-
Ecphyadophora	-	-	-	-	-	+
Helicotylenchus	+	+	+	+	+	-
Hoplolaimus	+	+	+	+	+	+
Longidorus	+	-	-	+	+	+
Meloidogyne	+	-	-	-	-	-
Trichodorus	-	-	-	-	+	-
Paratylenchus	-	-	-	+	+	-
Pratylenchus	+	+	+	+	+	+

Table 11 (Contd----)

Nematode	1	2	3	4	5	6
Radopholus	+	-	-	+	+	+
Rotylenchulus	+	-	+	+	+	+
Tylenchorhynchus	+	+	+	+	+	+
Tylenchus	-	-	-	+	+	-
Xiphinema	+	-	-	+	+	+

\+ present - absent

population associated with each palm. 50 g soil was processed for estimating VA mycorrhizal resting spores and 250 g soil was processed for nematode estimation according to the methods described earlier. The VA mycorrhizal root infection ranged from 0-100 per cent in the diseased palms where as healthy coconut palms recorded 20-100 per cent root infection. The VA mycorrhizal and nematode population associated with the diseased and healthy palms were identified (Table 12 and 13). The VA mycorrhizal species identified from the rhizosphere of healthy coconut palms were Acaulospora bireticulata, A. laevis, A. trappei, Gigaspora auriglobs, G. coralloidea, G. gilmorei, G. margarita, G. nigra, G. pellucida, Glomus fasciculatum, G. fuegianum, G. invermaium, G. macrocarpum, G. microcarpum, G. mosseae, G. pallidum, Sclerocystis clavispora, S. coremioides, S. microcarpum, S. rubiformis and S. sinuosa. Resting spores of A. bireticulata, G. fasciculatum, G. macrocarpum, G. gilmorei, S. clavispora and S. rubiformis were recovered from the rhizosphere of diseased palms.

Seasonal variation of VA mycorrhizal population

Variation in the population density of VA mycorrhizae associated with five coconut palms during different seasons was studied for one year from June 1989 to May 1990. Variation in the resting spore density in the soil and root infection were assessed every month. Root and soil samples of five elite coconut palms in the CPCRI farm were

Table 12

Mycorrhizal population in healthy and diseased coconut palms

Condition of the palms	Percentage root infection	VAMycorrhizal spores recovered from soil
HEALTHY	20-100	*Acaulospora bireticulata* *A. laevis* *A. trappei* *Gigaspora aurigloba* *G. coralloidea* *G. gilmorei* *G. margarita* *G. nigra* *G. pellucida* *Glomus fasciculatum* *G. fuegianum* *G. invermaium* *G. macrocarpum* *G. microcarpum* *G. mosseae* *G. pallidum* *Sclerocystis clavispora* *S. coremioides* *S. microcarpum* *S. rubiformis* *S. sinuosa*
DISEASED	0-100	*A. bireticulata* *G. fasciculatum* *G. macrocarpum* *G. gilmorei* *S. clavispora* *S. rubiformis*

Table 13

Nematodes associated with healthy and diseased coconut palms

Condition of the palm	Nematodes in roots	Nematodes in soil
Healthy	Radopholus similis Tylenchorhynchus coffeae	Aphelenchoides sp. Criconemoides sp. Ditylenchus sp. Dolichodorus pulvinus Helicotylenchus abunaamai Hoplolaimus seinhorsti Longidorus saginus Paratylenchus sp. Pratylenchus zeae Radopholus similis Rotylenchulus reniformis Trichodorus sp. Tylenchorhynchus coffeae Tylenchus sp. Xiphinema elongatum
Diseased	R. similis T. coffeae	X. elongatum H. abunaamai H. seinhorsti L. saginus P. zeae R. similis R. reniformis T. coffeae

collected every month at a distance of one metre away from the bole of the palm from four different depths viz. 0-25, 26-50, 51-75 and 76-100 cm using a two inch diameter iron pipe. The percentage of VAM infection in the fine fibrous feeder roots and the density of resting spores in the soil were assessed every month. The availability of fine fibrous feeder roots and corresponding endomycorrhizal infection in roots during dry and rainy season was also studied (Table 14). A dry spell of three to four months was succeeded by maximum spore recovery and increased root infection as presented in Figure 1 and 2. During rainy season and in the succeeding one or two months, the percentage root infection and resting spore recovery was less. Availability of fine feeder root bits while monthly sampling in relation to the pattern of rainfall is represented in Figure 3. The favourable season for VAM sampling is from January to April preferably in the month of April. Nematode and VA mycorrhizal population encountered in the rhizosphere of the five palms were also identified and presented in Table 15 and 16 .

15. Interaction studies :-

1. Interaction between R. similis and Glomus mosseae

An experiment was carried out with three month old WCT coconut seedlings grown in steam sterilised soil to study the interaction between burrowing nematode and VAM, Glomus mosseae. G. mosseae was selected for interaction studies

Table 14

Seasonal variation of VA mycorrhizal population associated with coconut palms

(av. of 5 palms)

Month	Rain (mm)	No. of feeder bits collected	Root infection (%)	No. of resting spores recovered from soil
June 1989	631.4	105	34	138
July	432.1	106	48	127
August	223.2	95	47	60
September	252.0	90	21	94
October	369.3	90	66	145
November	27.4	99	63	73
December	8.2	140	56	30
January 1990	32.8	299	67	131
February	4.4	261	59	188
March	35.0	306	78	119
April	83.0	114	90	2002
May	657.7	121	28	189

Figure 1

No of resting spores
In relation to pattern of rainfall

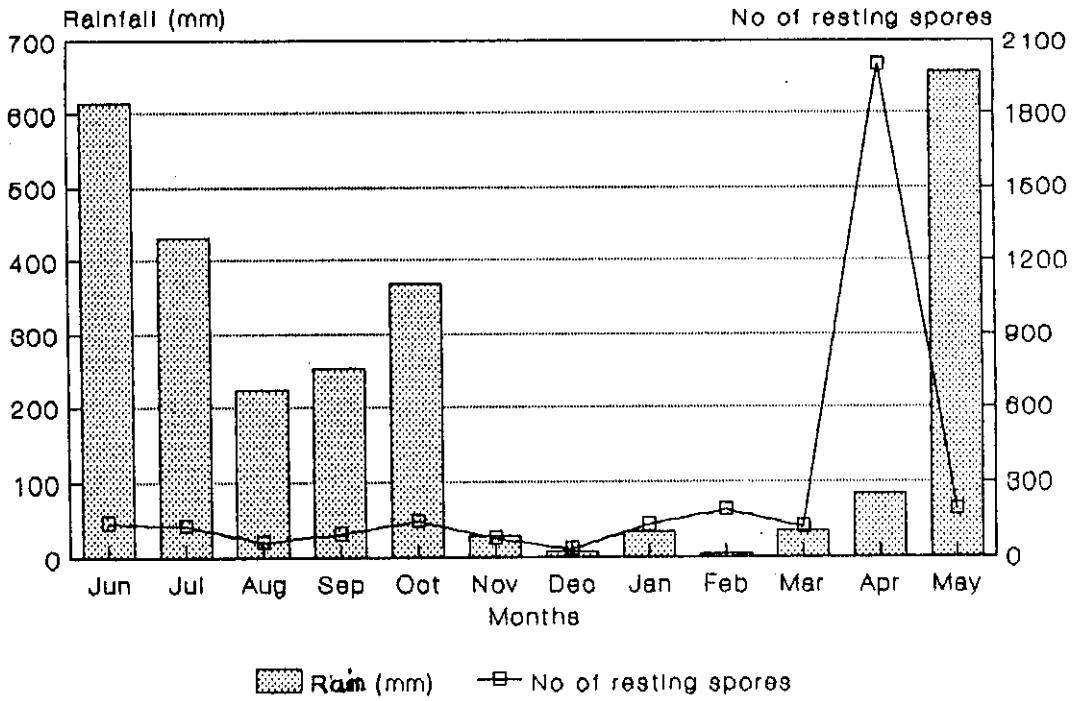


Figure 2

Percentage infection in roots
In relation to pattern of rainfall

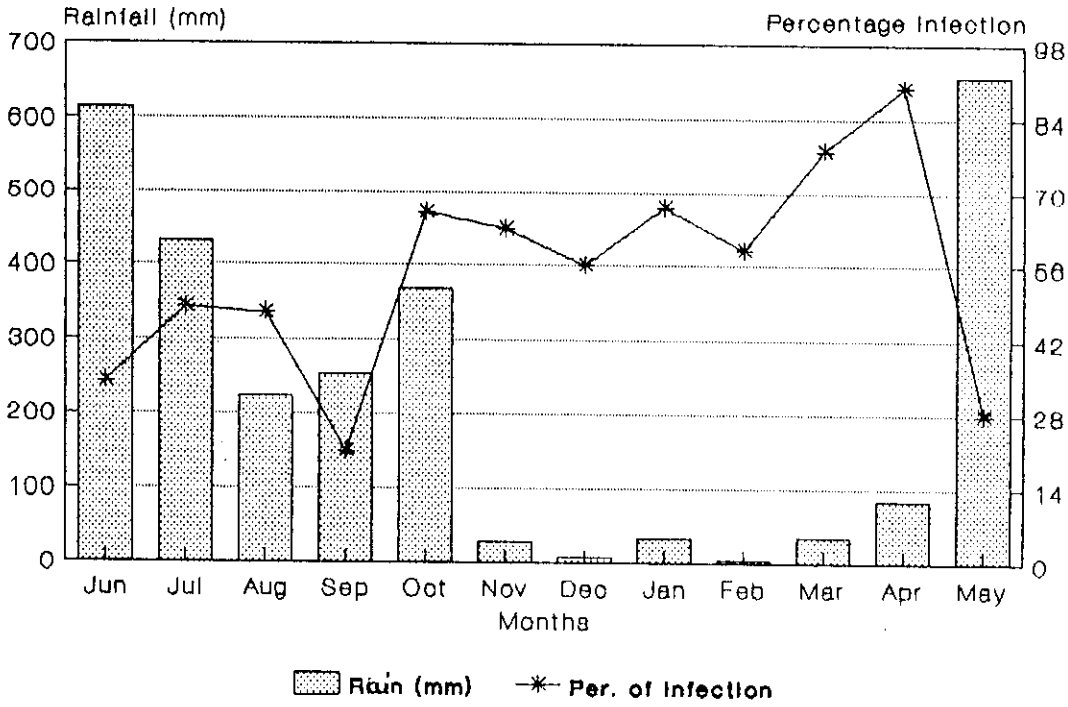


Figure 3

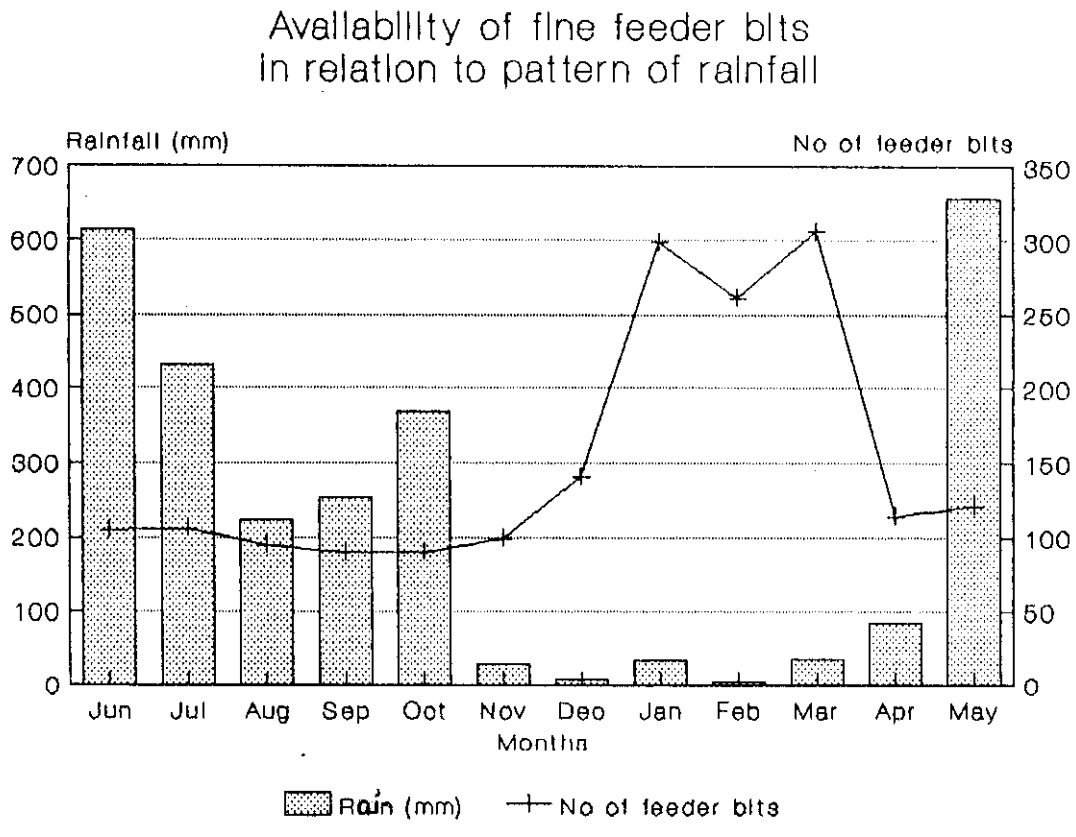

Availability of fine feeder bits
in relation to pattern of rainfall
Rainfall (mm)
No of feeder bits
700
600
500
400
300
200
100
0
350
300
250
200
150
100
50
0
Jun
Jul
Aug
Sep
Oct
Nov
Deo
Jan
Feb
Mar
Apr
May
Months
Rain (mm)
No of feeder bits

Table 15

Nematodes encountered in the rhizosphere of coconut palms in seasonal variation study

Palm	Nematodes
1	Criconemoides sp. , Helicotylenchus abunaamii, Hoplolaimus seinhorsti, Meloidogyne larvae, Pratylenchus zeae, R. reniformis, Tylenchorhynchus coffeae, Xiphinema elongatum.
2	Criconemoides sp., H. abunaamii, H. seinhorsti, Longidorus saginus, Paratylenchus sp., P. zeae, R. reniformis, R. similis, T. coffeae, X. elongatum.
3	H. abunaamai, H. seinhorsti, L. saginus, R. reniformis, R. similis, T. coffeae, X. elongatum.
4	H. abunaamai, H. seinhorsti, P. zeae, R. reniformis, T. coffeae, X. elongatum.
5	Aphelenchoides sp., Criconemoides sp., H. abunaamai, H. seinhorsti, L. saginus, P. zeae. R. reniformis, R. similis, X. elongatum.

Table 16

VAM species encountered in the rhizosphere soil of coconut palms under seasonal variation study

Palms	VAM species
1.	A. bireticulata, A. laevis, G. fasciculatum, G. mosseae, G. macrocarpum, Gigaspora pellucida, G. nigra, Sclerocystis rubiformis, S. coremioides.
2.	A. bireticulata, G. fasciculatum, G. fuegianum, G.macrocarpum, G. mosseae, Gigaspora nigra, G. coralloidea, S. rubiformis, S. coremioides.
3.	A. bireticulata, G. fasciculatum, G. macrocarpum, G. mosseae, Gigaspora gilmorei, S. rubiformis.
4.	A. bireticulata, G. fasciculatum, G. fuegianum, G. macrocarpum, G. mosseae, Gigaspora auriglobe, G. gilmorei, S. coremioides.
5.	A. bireticulata, G, fasciculatum, G. fuegianum, G. macrocarpum, G. mosseae, G. nigra, S. rubiformis, S. coremioides.

after conducting a preliminary screening trial of different VA mycorrhizae to assess the extent of root infection on coconut. The results showed that among the mycorrhizal species screened, higher per cent of infection was noticed in G. mossese (66 %) when compared to G. fasciculatum (60%) and G. versiforme (46 %). There were 14 treatments in the experiment with five replications each, consisting of seedlings inoculated with R. similis and G. mossese individually, G. mossese inoculated prior to, simultaneously or followed by different inoculum densities of R. similis viz. 50, 100 and 200 nematodes (larvae and females). The mycorrhizal inoculum consisted of 100 g soil and roots.

The treatments were

1. R. similis (50 nos)
2. R. similis (100 nos)
3. R. similis (200 nos)
4. G. mossese
5. G. mossese + R. similis (50)
6. G. mossese + R. similis (100)
7. G. mossese + R. similis (200)
8. R. similis (50) → G. mossese
9. R. similis (100) → G. mossese
10. R. similis (200) → G. mossese
11. G. mossese → R. similis (50)
12. G. mossese → R. similis (100)
13. G. mossese → R. similis (200)
14. Control.

The VA mycorrhizal population density in the inoculum was assessed to be around 4000 — 5000 Spores/100 g. The growth parameters of the experimental plants at the time of inoculation, at 6 months and after one year were recorded (Table 17, 18 and 19). The prior establishment of VAM was found to ameoliorate the ill effects of R. similis on coconut seedlings (Table 20 and 21). Maximum height of the plant was recorded in seedlings inoculated with G. mosseae alone (193 cm) followed by N_{50} + VAM (186 cm) and VAM → N_{50} (185 cm). Maximum leaf area was observed in plants treated with G. mosseae alone (8861 cm^2) followed by VAM → N_{50} (8319 cm^2) and control plants (8049 cm^2). Shoot and root weight was maximum in G. mosseae inoculated plants (930 g and 162 g respectively). In general, plants inoculated with G. mosseae alone recorded maximum growth parameters.

2. Interaction of different VA mycorrhizae with R. similis on coconut

An experiment was carried out in the greenhouse to study the effect of different VA mycorrhizae viz. Glomus mosseae, G. fasciculatum, G. versiforme and Gigaspora coralloidea, on the growth of coconut seedlings, and the efficacy of each of these VA mycorrhiza in suppressing the burrowing nematode multiplication on coconut and improving the growth of seedlings. The seedlings were raised in steam sterilized sandy loam soil in 14" earthern pots. The treatments were

Table 17

Growth parameters of coconut seedlings at the time of inoculation

Treatment	Height (cm)	Girth (cm)	No. of leaves	Lamina length (cm)	Lamina width (cm)
R. similis --50	85.2	8.9	2.6	42.2	14.4
R. similis 50 + *G. mosseae*	70	7.7	2	38.2	8.7
R. similis 50→ *G. mosseae*	89.5	8.2	2.4	54.6	12.02
G. mosseae→ *R. similis* 50	77	7.5	1.8	46.9	10.7
R. similis -- 100	83.6	8.1	2.8	41.9	12.2
R. similis 100 + *G. mosseae*	92.8	9.5	3.2	39.7	12.1
R.similis 100→*G. mosseae*	93.2	9.2	2.8	42.6	13.6
G. mosseae→ *R. similis* 100	88.9	9.9	3.2	41.7	12.08
R. similis -- 200	90.9	8.7	3.4	44.5	12.1
R. similis 200 + *G. mosseae*	89	9.3	3	40	11.9
R. similis 200→ *G. mosseae*	86	9.6	3	37.3	10.96
G. mosseae→ *R. similis* 200	91	9.7	3	41.9	11.9
G. mosseae	91	10.3	2.8	42.9	11.6
Control	91.6	10.3	3.4	38.7	12.3

Table 18

Effect of Radopholus similis and G. mossae alone, and in combination on growth parameters of coconut seedlings six months after inoculation

Treatments	Height (cm)	Girth (cm)	No. of leaves	Lamina length (cm)	Lamina width (cm)
N - 50	116.8	11.2	4.8	57.06	18.8
N50 + VAM	133.2	9	4.2	63.7	14.5
N_{50}→ VAM	138.2	11.2	4.8	64.3	17.2
VAM→ N_{50}	146.8	10.8	4	69.5	17.08
N - 100	140	10.6	4.6	58.5	16.4
N_{100}+ VAM	143.8	12.4	5.2	60.4	18.4
N_{100}→ VAM	132.8	11.2	4.8	57.8	17.3
VAM → N_{100}	127.4	11.4	5	53.3	16.2
N - 200	129.2	11.4	5	60	17.2
N_{200} + VAM	128.8	11.2	4.8	57.2	17.8
N_{200} → VAM	133.2	10.8	5.2	55.08	16.5
VAM → N_{200}	133	11.8	4.6	57	16.7
VAM alone	146.6	12.2	5	61.9	17.6
Control	126	11.8	5.2	55.7	17.9

Table 19

Effect of Radopholus similis and G. mosseae alone and in combination on growth parameters of coconut seedlings one year after inoculation

Treatments	Height (cm)	Girth (cm)	No. of leaves	Lamina length (cm)	Lamina width (cm)
N - 50	122.4	13.2	5.6	65.74	20.02
N_{50} + VAM	179.4	12	7	72.08	20.38
N_{50} -> VAM	144	11.8	6.4	69.02	20.19
VAM -> N_{50}	151	10.6	6.2	71.28	20.67
N -- 100	151.2	12.2	5.8	73.82	19.80
N_{100} + VAM	159.6	12.4	6.2	80.39	23.17
N_{100} -> VAM	151.6	12	6.2	73.68	21.6
VAM -> N_{100}	148.4	11.4	7	71.61	22.48
N -- 200	146.6	12.8	6	74.86	21.15
N_{200} + VAM	175.5	12.5	7	74.96	21.88
N_{200} -> VAM	145.4	10.6	7	69.99	21.13
VAM -> N_{200}	148.2	11.4	6	73.20	18.72
VAM alone	185.4	12.0	6.6	86.17	21.08
Control	156.4	12.8	6.8	77.47	20.89

Table 20

Effect of Radopholus similis and Glomus mossecae alone and in combination on the growth of Coconut seedlings

Treatment	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)	No. of live main roots	Maximum root length (cm)	Rpot wt (g)	Shoot wt (g)
N_{50}	138	13	7	5645.94	8	90	56	300
N_{50} → VAM	163	13	7	5873.49	8	93	118	378
N_{50} + VAM	186	14	7	7655.81	11	102	104	795
VAM → N_{50}	185	12	7	8318.78	11	116	136	830
N_{100}	158	14	6	5369.00	4	73	78	530
N_{100} → VAM	154	12	7	6726.60	6	82	60	615
N_{100} + VAM	165	15	6	6789.76	8	91	87	709
VAM → N_{100}	150	13	7	7080.78	11	98	91	782
N_{200}	147	16	6	4898.41	4	58	66	350
N_{200} → VAM	158	13	6	5864.17	6	74	52	378
N_{200} + VAM	181	14	8	6314.10	9	88	83	474
VAM → N_{200}	162	14	7	6827.18	14	95	87	815
VAM alone	193	14	7	8861.39	14	174	162	930
Control	158	13	7	8048.87	14	152	130	813

Interactive effect of *Radopholus similis* and *Glomus mosseae* alone and in combination on coconut seedlings

Treatment	Root weight (g)	Shoot weight (g)	Lesion index	Nematode Population		VAM Population	
				Root	Soil/250g	Root infection (%)	Resting spores (50g soil)
N_{50}	56	300	3	2883	32	-	-
N_{50} → VAM	118	378	4	600	14	22.5	183
N_{50} + VAM	104	795	3	1063	150	55	200
VAM → N_{50}	1361	830	2	212.5	25	66.6	250
N_{100}	78	530	5	3661	34	-	-
N_{100} → VAM	60	615	4	6338	48	66.6	166
N_{100} + VAM	87	709	3	3350	82	35	116
VAM → N_{100}	91	782	3	8404	97	67.7	183
N_{200}	66	350	4	8800	119	-	-
N_{200} → VAM	52	378	4	5967	109	40	133
N_{200} + VAM	83	474	4	8350	111	34.5	100
VAM → N_{200}	87	815	3	4211	118	16.25	83
VAM alone	162	930	-	-	-	76	283
Control	130	813	-	-	-	-	-

T_1 Control

T_2 *G. mosseae*

T_3 *G. fasciculatum*

T_4 *G. versiforme*

T_5 *Gigaspora coralloidea*

T_6 *G. mosseae* → *R. similis*

T_7 *G. fasciculatum* → *R. similis*

T_8 *G. versiforme* → *R. similis*

T_9 *Gigaspora coralloidea* → *R. similis*

T_{10} *R. similis* alone

Nematode inoculation was carried out one month after the inoculation of VAM. In all treatments the nematode inoculum consisted of 100 numbers of R. similis and VAM inoculum consisted of 100 g soil and root of each culture. Each treatment had 5 replications. One year after inoculation, the plants were carefully depotted and the root system washed well with water to remove the adhering soil particles. Plant growth parameters viz. height, girth, number of leaves, leaf area, root and shoot weight were recorded for each plant. The soil in each pot was emptied into a big tray, mixed well and an aliquot of 250 cm^3 of soil was drawn out and processed for nematode estimation. Another 50 g soil was washed and processed for VA mycorrhizal spore estimation. Coconut seedlings inoculated with *G. mosseae* recorded maximum growth characters when compared to seedlings that were inoculated with *G. fasciculatum*, *G. versiforme* and *Gigaspora coralloidea* individually.

But when these mycorrhizae were screened for their interactive effect with the burrowing nematode, Radopholus similis Gigaspora coralloidea proved to be the best followed by G. fasciculatum (Table 22 and 23).

3. Interaction of VAM isolated from healthy high yielding coconut palms viz. Acaulospora sp., Gigaspora sp., Glomus sp., and Sclerocystis sp. with burrowing nematode on coconut

An experiment was conducted under greenhouse conditions with mycorrhizae isolated from elite coconut palms to find out the most effective VAM in suppressing R. similis multiplication on coconut (WCT). There were ten treatments with five replications each. The treatments were

1. Acaulospora bireticulata
2. Gigaspora coralloidea
3. Glomus macrocarpum
4. Sclerocystis rubiformis
5. R. similis
6. A. bireticulata → R. similis
7. G. coralloidea → R. similis
8. G. macrocarpum → R. similis
9. S. rubiformis → R. similis
10. Control

VAM inoculum consisted of 100 g soil + root of each culture and R. similis inoculum consisted of 100 numbers of R. similis (females and larvae). VAM inoculation was done on the 30 th of September 1992, 40 days prior to nematode

Table 22

Effect of R. similis and different VA mycorrhizae alone and in combination on the growth of coconut seedlings in the greenhouse (av. of 5 seedlings)

Treatment	Height (cm)	Girth (cm)	No. of leaves	Total leaf area (cm^2)	Shoot weight		Root weight	
					Wet (g)	Dry (g)	Wet (g)	Dry (g)
Control	145	9.8	6	3432.56	304	68.92	61.4	9.7
G. mosseae	165	11.8	5.6	4962.50	227	57	67	15.5
G. m → R. similis	159	9.8	5.6	4083.75	307	69.26	43.2	8.65
G. fasciculatum	146	9.6	5.8	4052.80	282	72	65	13
G. f → R. similis	149	10.4	5.6	3815.07	233.2	64.06	45.4	11.05
G. versiforme	155	10	4.8	3775.84	341	77	53	11.92
G. v → R. similis	153	10	6	3905.29	325	72	50	11
Gigaspora coralloidea	157	12	5.6	4377.54	273	67	54.8	13.39
Gigaspora → R. similis	166	10	5.8	4435.63	338	80	52	10.66
R. similis	149	9.6	5.6	2947.63	266	53	39	7.53

Table 23

Effect of interaction of R. similis and different VAM alone and in combination on the population build up of VAM and nematode on coconut seedlings (av. of 5 seedlings)

Treatment	VAM population		Nematode population	
	Root infection (%)	Resting spores (50 g soil)	Root (50 g)	Total nematode population (Root + Soil)
Control	-	-	-	-
G. mossese	70	120	-	-
G. m → R. similis	32	90	55	620
G. fasciculatum	50	103	-	-
G. f → R. similis	28	60	10	97
G. versiforme	72	104	-	-
G. v → R. similis	30	127	55	2211
Gigaspora coralloidea	48	80	-	-
G. c → R. similis	42	97	60	1470
R. similis	-	-	2260	16635

inoculation. The plants were depotted after one year and the nematode and mycorrhizal population were assessed as described in the previous experiment. On interaction with burrowing nematode as well as when inoculated individually, Acaulospora bireticulata proved to have the best effect on plant growth and nematode suppression. In the interaction studies, there was reduction in the nematode population as well as mycorrhizal population when compared to that when inoculated individually (Table 24 and 25). It was clear that the VAM could not bring complete control of the burrowing nematode but could suppress their multiplication to a certain extent. Maximum height and leaf area was recorded in seedlings inoculated with A. bireticulata and maximum reduction in growth was recorded in seedlings inoculated with burrowing nematode. The fact that VA mycorrhizal colonisation could not bring complete control of the burrowing nematode is supporting the general conception that VA mycorrhizae are not effective against migratory endoparasitic nematodes.

4. Interaction of a mixture of VA mycorrhizae with R. similis on coconut seedlings

In this experiment coconut seedlings, variety West Coast Tall were raised in steam sterilised soil in 35 cm earthen pots in the greenhouse. Thirty coconut seedlings (three month old) having uniform growth were selected and used. There were six treatments, each replicated five times.

Table 24

Interactive effect of burrowing nematode and different VAM on shoot and root growth characters of coconut seedlings (av. of 5 seedlings)

Treatments	Height (cm)	Girth (cm)	No. of leaves	Total leaf area (cm^2)	wet Shoot weight (g)	wet Root weight (g)	Lesion index
A. b	298	15	7	8863.10	770	178	-
G. c	264	16	8	8318.26	716	166	-
G. m	256	16	7	8526.40	816	156	-
S. r	242	15	7	8325.17	772	135	-
R. s	172	15	7	7369.90	440	102	4
A. b → R. s	202	15	8	7927.60	698	158	2
G. c → R. s	210	16	7	7655.41	508	148	2
G. m → R. s	238	15	7	7632.18	684	154	2
S. r → R. s	220	16	7	7520.40	620	150	2
Control	240	15	7	8124.76	688	160	-

A. b - A. bireticulata
G. c - G. coralloidea
G. m - G. macrocarpum
S. r - S. rubiformis
R. s - R. similis

Table 25

Interactive effect of burrowing nematode and different VAM (applied individually) on the population build up of nematode and VAM on coconut seedlings

Treatments	Nematode population		VAM population	
	Root	Soil (250g)	Resting spores (50 g soil)	Root infection (%)
A. bireticulata	-	-	140	84
G. coralloidea	-	-	83	72
G. macrocarpum	-	-	84	78
S. rubiformis	-	-	80	74
R. similis	186	23	-	-
A. b → R. similis	66	32	16	60
G. c → R. similis	104	20	14	60
G. m → R. similis	153	12	32	50
S. r → R. similis	123	14	14	10
Control	-	-	-	-

A. b - A. bireticulata

G. c - Gigaspora coralloidea

G. m - Glomus macrocarpum

S. r - Sclerocystis rubiformis

the treatments were

T_1 - Control

T_2 - *R. similis*

T_3 - VAM

T_4 - VAM + *R. similis*

T_5 - VAM → *R. similis*

T_6 - *R. similis* → VAM

Coconut isolate of *R. similis* axenically multiplied on carrot discs was used for inoculation. VAM inoculum consisted of a mixture of different mycorrhizae viz. *Acaulospora bireticulata*, *Glomus fasciculatum*, *G. macrocarpum*, *G. mosseae*, *G. versiforme*, *Gigaspora nigra* and *Sclerocystis rubiformis* in equal proportion. In treatments T_5 and T_6, there was 35 days interval between the two inoculations. The *R. similis* inoculum consisted of 300 numbers of larvae and females. Soil around the roots were removed to expose the root system and then the inoculations were carried out by adding the respective inoculum over the exposed root system. After inoculation the roots were again covered with soil. All the pots were kept in the greenhouse with even sunlight and watered daily with boiled and cooled water. The temperature in the greenhouse varied from 27 to 34° C.

Eight months after inoculation the plants were carefully depotted and the root system washed thoroughly to remove the adhering soil particles. Plant growth parameters such as height, girth, number of leaves, lamina length and breadth, root weight and shoot weight were

recorded. Nematode population from 250 cm^3 of soil was assessed from each pot. Nematode and percentage infection of VAM in roots were also assessed. Resting spores in soil was assessed from 50 g soil from each pot.

From the results, treatment differences were found to be significant in the case of lamina width and total leaf area. In both the cases VAM plants (T_3) was found to record the highest value closely followed by VAM followed by nematode (T_5). Minimum lamina width and leaf area were observed in nematode treated plants (T_3). Statistically significant differences were recorded in all characters such as shoot weight,,root weight, maximum root length and lesion index. Maximum growth characters were recorded in VAM inoculated seedlings. There was no significant difference in the case of number of roots (Table 26 and 27). Nematode population in the root was highest in the seedlings inoculated with burrowing nematode alone. Nematode population in the soil and root was less in the seedlings where the VAM was inoculated prior to the nematode. Nematode population in the soil and root was less in the seedlings where the VAM was inoculated prior to nematode. This supports the view that prior colonisation of VAM can reduce the nematode multiplication. Maximum VA mycorrhizal root infection and resting spores were recorded in the VAM alone inoculated mycorrhizal seedlings (Table 27).

7. Screening of nematicides to find out an effective nematicide

Effect of interaction of VAM and R. similis on shoot growth characters of coconut

Treatments	Height (cm)	Girth (cm)	No. of leaves	Lamina length (cm)	Lamina breadth (cm)	Leaf area (cm^2)	Shoot weight (g)
Control	215.4	12.8	8.2	103.5	25.0	1.33	454
Nematode	206.0	12.6	8.4	95.8	22.2	1.28	298
VAM	251.8	14.6	9.6	108.4	26.8	1.77	494
VAM + N	228.2	13.4	9.0	100.2	24.0	1.43	406
VAM → N	247.6	13.6	9.6	107.6	26.4	1.76	444
N → VAM	207.2	13.8	9.0	100.6	24.0	1.42	322
Gen. mean	226.0	13.5	9.0	102.7	24.7	1.48	403
CV (%)	14.5	10.3	12.1	8.1	7.8	16.12	11.4
F ratio	1.85	1.35	1.45	1.67	3.85*	4.91**	14.35**
CD at P = 0.05	NS	NS	NS	NS	2.52	0.31	59.73

** significant at P = 0.01 * significant at P = 0.05 NS - Not significant

Table 27

Effect of interaction of VAM and R. similis on root growth characters, nematode and VAM population

Treatments	No. of roots	Maximum root length (cm)	Root weight (g)	Lesion index	R. similis population		VAM	
					soil (250 g)	root (50 g)	Resting spores (50 g soil)	Percentage root infection
Control	6.6	102	102.0	0	0	0	0	0
Nematode	7.4	77	83.8	4.0	15.0	2289	0	0
VAM	7.2	97	133.2	0	0	0	376	80
VAM + N	7.8	66	96.0	2.4	7.6	1108	137	33
VAM → N	7.4	79	107.2	1.8	6.2	600	130	48
N → VAM	6.2	90	79.2	3.2	43.8	1007	150	28
Gen. mean	7.1	85.2	100.2	1.9	12.1	828.8	132.3	31.5
CV %	15.7	16.0	8.4	41.3	277.1	89.5	24.9	22.8
F ratio	1.39	4.96*	26.48**	21.02**	1.21	6.51**	87.38**	89.49**
CD at P = 0.05	NS	17.78	10.94	1.02	NS	966.11	42.94	9.37

** significant at P = 0.01 * significant at P = 0.05 NS - Not significant

with least deleterious effect on VA mycorrhizae

The experiment to study the effect of different nematicides viz. Phorate, Furadan and Rugby on VAM colonisation on coconut in the field was done in Block VI and VII of CPCRI, Farm, Kayangulam. Root and soil samples were drawn from a total of 57 coconut palms (32 apparently healthy and 25 root (wilt) disease early) and examined to assess the nematode population and VA mycorrhizal population (Table 28) associated with each palm. Of the 32 apparently healthy palms, 19 palms showed 100 per cent root colonisation of VAM and the percentage infection ranged from 30-100 per cent in the apparently healthy palms. Of the 25 disease early palms, 14 palms yielded 100 per cent root infection and the VA mycorrhizal colonisation in the disease early palms ranged from 30-100 per cent . From this 20 apparently healthy palms with VAM root infection ranging from 70-100 per cent and 20 disease early palms with VAM root infection ranging from 70-100 per cent were selected for nematicide treatment trial. The pre-treatment nematode population identified from the soil were Criconemoides sp., Ditylenchus sp., Helicotylenchus abunaamai, Hoplolaimus seinhorsti, Longidorus saginus, Meloidogyne larvae, Paratylenchus sp., Pratylenchus zeae Radopholus similis, Rotylenchulus reniformis and Xiphinema elongatum. Five root samples yielded R. similis. The VAMycorrhizal resting spores found in the rhizosphere of these palms were of Acaulospora spp., Gigaspora spp., Glomus spp., and Sclerocystis spp.,. Three nematicides

Table 28

VA mycorrhizal colonisation in apparently healthy and disease early coconut palms screened for nematicide application trial

Apparently healthy palms	VAM infection(%)	Disease early palms	VAM infection(%)
1	100	1	100
2	100	2	100
3	100	3	100
4	100	4	30
5	70	5	100
6	100	6	90
7	80	7	40
8	70	8	90
9	100	9	50
10	40	10	100
11	100	11	100
12	30	12	100
13	30	13	80
14	100	14	60
15	60	15	40
16	60	16	70
17	90	17	100
18	100	18	100
19	100	19	100
20	100	20	90
21	90	21	90
22	100	22	100
23	100	23	100
24	100	24	100
25	100	25	100
26	100	26	100
27	90		
28	100		
29	100		
30	60		
31	80		
32	100		

viz. Carbofuran, Phorate and Ebufos @ 10 g a.i./palm were applied to ten palms each. Ten palms (Five apparently healthy and five disease early) were retained as control. Each treatment consisted of five apparently healthy and five disease early palms. Prior to every nematicide application, the basins of all palms were opened and cleaned free of weeds. Samples were collected at a distance of one metre away from the bole of the palm to a depth of 100 cm. Root and soil samples were drawn prior to each application, processed and examined to assess the nematode and VA mycorrhizal population associated with each coconut palm. The roots were collected and the nematodes were extracted. The percentage VAM colonisation was also assessed in terms of the presence of hyphae, vesicles, arbuscules and spores. The percentage of VAM infection in coconut roots in pre-treatment samples and prior to the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, and 8th application were 98, 35, 62, 56, 36, 23, 32, 31 for Furadan, 96, 54, 80, 78, 68, 43, 49 and 47 for Phorate and 94, 46, 77, 74, 44, 33, 38 and 36 for Ebufos. The VAM infection in the control palms were 89, 68, 89, 90, 98, 70, 82 and 80. Forty per cent of the palms yielded Hoplolaimus seinhorsti, 10 per cent yielded Helicotylenchus abunaamai, 10 per cent yielded Rotylenchulus reniformis, 2.5 per cent yielded Criconemoides sp., 10 per cent yielded Longidorus saginus, 7.5 per cent yielded Pratylenchus zeae and 40 per cent yielded Xiphinema elongatum and 23 per cent of the palms yielded R. similis. The VA mycorrhizal resting spores

encountered in the rhizosphere were identified as Acaulospora sp., Gigaspora sp., Glomus sp., and Sclerocystis sp., (Table 29).

The three nematicides Carbofuran, Ebufos and Phorate were applied @ 10 g a.i/palm, twice a year for four years. Sampling was done prior to each nematicide application and the nematode and mycorrhizal population were estimated. Even after the seventh nematicide application, Phorate proved to be the best nematicide with least deleterious effect on VA mycorrhizal population (Table 30).

Yield data of the experimental palms were also recorded periodically (Table 31-34).

8. Studies on population build up of VA mycorrhizae and burrowing nematode under field condition in high density multispecies cropping systems including coconut by introduction of mycorrhizal plants

Nematode free mycorrhizal(Glomus mossea colonized) seedlings of coconut var. WCT(7 Nos.), arecanut var.Mangala(10 Nos Pepper cv. Karimunda (5 Nos.), Cacao var. Forestro (8 Nos.) cloves (7Nos.) and banana var. Njalipoovan (5 Nos.) were raised individually in steam sterilised soil in earthen pots in the greenhouse. Coconut seednuts were dehusked retaining the mesocarp fibre above the fertile eye and sown in sterile soil contained in 35 cm earthern pots while arecanut seed nuts were sown as such in similar pots. Banana suckers were pared, dipped in ten per cent Dithane M_{45} suspension and then

Table 29

VA mycorrhizal resting spores encountered in the basins of coconut palms treated with nematicide

Treatment	Endo mycorrhizal spore types recovered
Control	Acaulospora bireticulata, Glomus fasciculatum, G. macrocarpum, G. mosseae, Gigaspora pellucida and Sclerocystis rubiformis.
Ebufos	A. bireticulata, G. fasciculatum, G. macrocarpum, G. mosseae, Gigaspora auriglobe, S. coremioides and S. rubiformis.
Phorate	A.bireticulata, A.laevis, A. trappei, G. fasciculatum, G. macrocarpum spores and sporocarps, G. mosseae spores and sporocarps, G. pellucida, S. clavispora, S. coremioides and S. rubiformis.
Furadan	A. bireticulata, A. laevis, A. trappei, G. fasciculatum, G. macrocarpum and S. rubiformis.

Table 30

Effect of nematicides on VAM colonisation in coconut roots

Nematicide	Percentage infection							
	Pre-treatment samples	Post Application						
		1	2	3	4	5	6	7
Carbofuran	98	35	62	56	36	23	28	51
Phorate	96	54	80	78	68	43	74	67
Ebufos	94	46	77	74	44	33	29	56
Control	89	68	89	90	98	70	79	80

Table 31

Yield data of experimental palms (Apparently healthy and disease early palms) prior to nematicide application (av. of 5 palms each)

Treatments	Apparently healthy			Diseased		
	Total nuts	Total No. of bunches	Total No. of inflorescences	Total Nuts	Total No. of bunches	Total No. of inflorescences
Carbofuran	73	9	10	51	8	9
Phorate	65	9	9	43	7	9
Ebufos	62	10	11	47	9	9
Control	49	8	9	43	8	9

Table 32

Yield data of Nematicide applied palms - 1990 (av. of 5 palms each)

Treatments	Apparently healthy			Diseased		
	Nuts	Bunches	Inflorescences	Nuts	Bunches	Inflorescences
Carbofuran	75	7	7	27	7	8
Phorate	37	6	7	12	5	7
Ebufos	39	7	8	28	8	8
Control	30	7	8	17	6	7

Table 33

Yield data of Nematicide treated palms - 1991 (av. of 5 palms each)

Treatments	Apparently healthy			Diseased early		
	Nuts	Bunches	Inflorescence	Nuts	Bunches	Inflorescence
Carbofuran	70	11	12	69	12	14
Phorate	79	14	14	29	12	13
Ebufos	78	12	11	46	11	13
Control	39	9	14	33	10	13

Table 34

Yield data of Nematicide treated palms - 1992 (av. of 5 palms)

Treatments	Apparently healthy			Disease early		
	Nuts	Bunches	Inflorescences	Nuts	Bunches	Inflorescences
Carbofuran	49	8	8	45	10	10
Phorate	61	11	11	24	7	9
Ebufos	78	10	11	38	8	10
Control	55	9	10	43	9	12

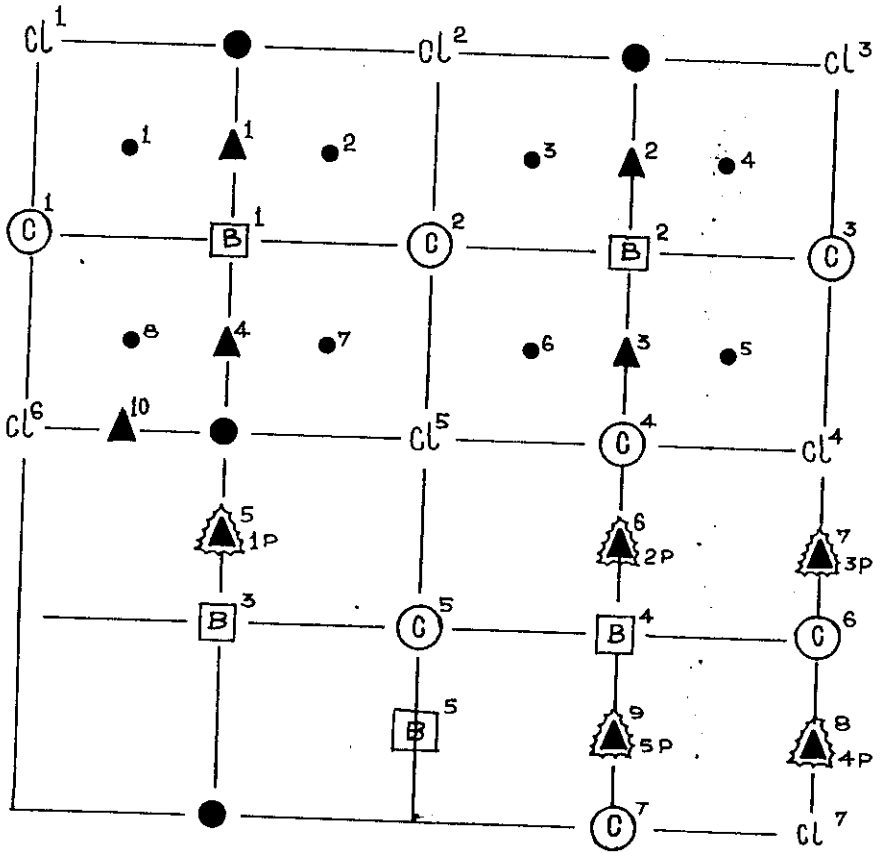
treated with phorate @ 0.05 g/ccc of soil. They were sown in 35 x 25 x 7.5 cm aluminium trays. After 45 days the plants were depotted, washed and all roots were removed and planted in 35 cm earthen pots containing sterile soil. The mycorrhizal inoculation was carried out in January, 1990. Equal number of seedlings of the above mentioned crops were maintained as control plants in pots containing steam sterilised soil. The planting of the seedlings in the field was done six months after the mycorrhizal inoculation. A coconut monocropped plot was selected for the field trial, cleaned off weeds and was equally divided into two halves viz. a mycorrhizal plot where the mycorrhizal seedlings were planted and a control plot where uninoculated (non mycorrhizal) seedlings were planted (Fig. 4).

The seedlings were planted in the field to form a mini-model of a coconut based high density multispecies cropping system. Soil samples were collected from the experimental plot prior to the planting of the seedlings and the nematode and mycorrhizal population present in the field prior to the initiation of the experiment was assessed. The nematodes identified were of Hoplolaimus seinhorsti, Criconemoides spp., and R. similis. The native VAMycorrhizal population were identified as Acaulospora sp., Gigaspora sp. and Glomus sp.

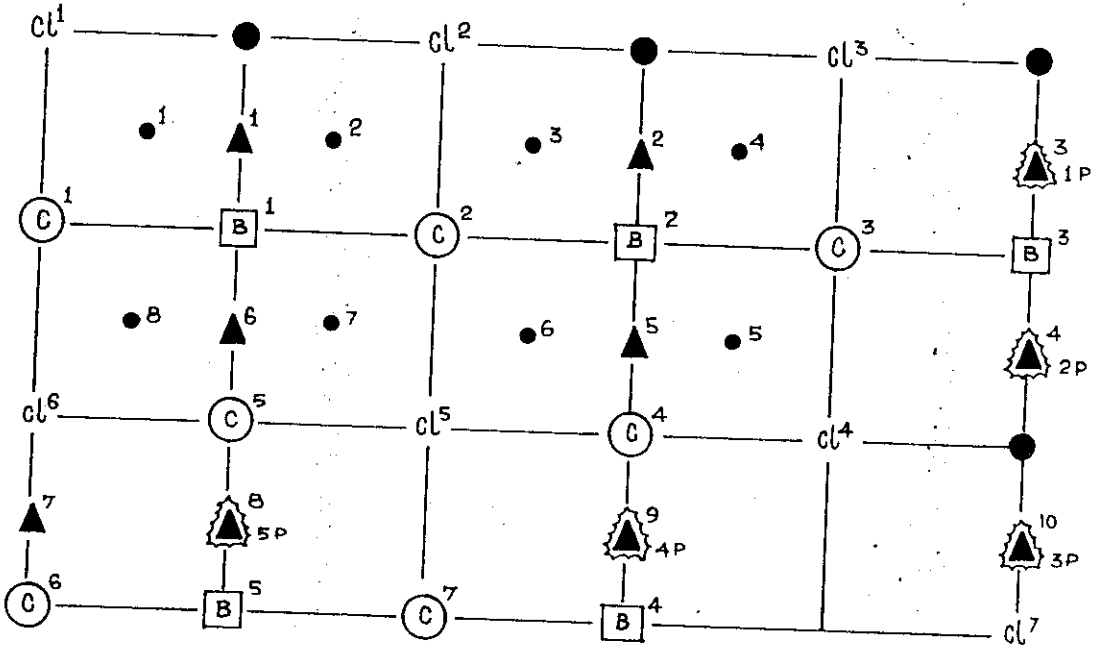
The influence of VA mycorrhiza on the growth of the seedlings was studied by recording the growth parameters viz. height, girth, number of leaves, lamina length, lamina breadth, vine length (pepper), leaf area etc periodically (Tables 35 to

HDMSCS DESIGN

CONTROL PLOT



MYCORRHIZAL PLOT



C Coconut seedlings

● Bearing coconut palms

• Cocoa

▲ Arecanut

Pepper

B Banana

Cl Cloves

Spacing : Coconut – Coconut : 7.4 m

Table 35

Growth parameters of control and mycorrhizal coconut seedlings in the HDMSCS plot (mean of 7 plants)

	At planting				After one year			
	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)
Control	102.71	8.86	3.71	1266.47	231.71	24.43	14.43	25593.89
Mycorrhizal	103.71	8.71	3.00	1768.37	247.71	33.57	14.71	52757.47
Gen. mean	103.21	8.79	3.36	1517.42	239.71	29.00	14.57	39125.68
CV (%)	16.57	9.46	15.92	33.33	19.91	17.79	6.61	60.60
F ratio	0.01	0.10	6.52*	3.45	0.39	10.99**	0.31	4.58
	NS	NS		NS	NS		NS	NS

** significant at P= 0.01 * significant at P= 0.05 NS - Not significant

(contd.....Table 36)

Table 36

Growth parameters of control and mycorrhizal coconut seedlings in the HDMSCS plot (mean of 7 plants)

	After two years				After three years			
	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)
Control	286.86	40.43	19.00	68932.54	334.57	46.57	22.00	99820.07
Mycorrhizal	381.00	55.71	19.57	120334.35	416.57	67.71	23.43	227046.09
Gen. mean	333.93	48.07	19.29	94633.45	375.57	57.14	22.71	163433.08
CV (%)	18.30	23.37	5.54	38.45	18.40	25.14	5.92	66.89
F ratio	8.31*	6.48*	1.00 NS	7.06*	4.93 NS	7.58*	3.95 NS	4.74 NS

** significant at P = 0.01 * significant at P = 0.05 NS - Not significant

Table 37

Growth parameters of control and Mycorrhizal Arecanut seedlings in the HDMSCS plot

Treatment	At planting				After one year			
	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)
Control	40.80	3.05	1.80	4.85	83.30	8.45	7.90	12.79
Mycorrhizal	43.90	3.32	2.00	4.99	118.90	10.95	8.90	15.20
Gen. mean	42.35	3.19	1.90	4.92	101.10	9.70	8.40	13.99
CV (%)	13.41	12.25	15.69	24.50	45.72	28.59	11.15	14.93
F ratio	1.49	2.39	2.25	0.08	2.97	4.06	5.70*	6.65*
CD (P= 0.05)	NS	NS	NS	NS	NS	NS		

** significant at P = 0.01 * significant at P= 0.05 NS - Not significant

(Contd.....Table 38)

Table 38

Growth parameters of control and mycorrhizal Arecanut seedlings in the HDMSCS plot

Treatment	After two years				After three years			
	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)	Height (cm)	Girth (cm)	No. of leaves	Leaf area (cm^2)
Control	241.60	20.70	12.80	21.30	233.50	32.10	16.50	29.22
Mycorrhizal	182.30	24.70	13.90	23.63	261.10	36.60	17.50	30.83
Gen. mean	211.95	22.70	13.35	22.46	247.30	34.35	17.00	30.02
CV (%)	87.76	25.23	8.37	10.07	24.85	28.00	7.20	10.11
F ratio	0.51	2.44	4.84*	5.31*	1.01	1.09	3.33	1.41
CD (P = 0.05)	NS	NS			NS	NS	NS	NS

** significant at P= 0.01 * significant at P= 0.05 NS - Not significant

Table 39

Growth parameters of control and mycorrhizal cacao plants in the HDMSCS plot

Treatment	At planting		After one year	
	Shoot length (cm)	No. of leaves	Shoot length (cm)	No. of leaves
Control	23.00	9.75	38.00	25.13
Mycorrhizal	24.50	11.50	52.13	29.38
Gen. mean	23.75	10.63	45.06	27.25
CV (%)	10.56	15.40	40.69	34.63
F ratio	1.43	4.57	2.37	0.81
CD(P = 0.05)	NS	NS	NS	NS

NS - Not significant

Table 40

Growth parameters of control and mycorrhizal cacao seedlings in the HDMSCS plot

Treatment	After two years		After three years	
	Shoot length (cm)	No. of leaves	Shoot length (cm)	No. of leaves
Control	58.00	41.88	155.75	117.75
Mycorrhizal	92.38	69.13	374.00	248.25
Gen. mean	75.19	55.50	264.89	183.00
CV (%)	40.36	48.00	117.63	90.62
F ratio	5.13*	4.19	1.96	2.48
CD (P = 0.05)		NS	NS	NS

* significant at P = 0.05 NS - Not significant

Table 41

Growth parameters of control and mycorrhizal clove seedlings in the HDMSCS plot

Treatment	At planting		After one year	
	Shoot length (cm)	No. of leaves	Shoot length (cm)	No. of leaves
Control	16.29	14.29	14.57	21.57
Mycorrhizal	19.14	17.71	75.29	48.57
Gen. mean	17.71	16.00	19.93	35.07
CV (%)	14.60	13.36	35.81	49.89
F ratio	4.27	9.00*	7.89*	8.34*
CD (P = 0.05)	NS			

** significant at P = 0.01 * significant at P = 0.05 NS - Not signicicant

Table 42

Growth parameters of control and mycorrhizal clove seedlings in the HDMSCS plot

Treatment	After two years		After three years	
	Shoot length (cm)	No. of leaves	Shoot length (cm)	No. of leaves
Control	19.29	25.14	27.43	29.43
Mycorrhizal	37.43	91.57	102.43	215.14
Gen. mean	28.36	58.36	64.93	122.29
CV (%)	45.90	89.99	23.63	42.26
F ratio	6.80*	5.60*	83.62**	45.21**
CD (P= 0.05)				

** significant at P= 0.01 * significant at P= 0.05 NS Not significant

42). The increase in the growth of mycorrhizal seedlings when compared to the control plants supports the growth promoting ability of VAM. All the banana plants in the control and mycorrhizal plot came to bearing. There was significant increase in the bunch weight and other growth characters in the mycorrhizal plants. There was 18.02 per cent increase in height, 2.54 per cent increase in number of leaves, 30.69 per cent increase in leaf area, 35.66 per cent increase in bunch weight, 30 per cent increase in the number of hands, 39.57 per cent increase in the number of fingers and 30.07 per cent increase in the shoot weight in the mycorrhizal plants when compared to that of control banana plants in the field (Table 43). The nematode and mycorrhizal population associated with the control and mycorrhizal banana plants were also assessed (Table 44). Comparison of various growth characters of the control and mycorrhizal banana plants are given in Table 45 . Analysis of growth characters of 4 generations of banana plants on the control and mycorrhizal plots are presented in Table 46a and b. Banana plants in the mycorrhizal plot gave significantly higher values in the case of height, number of leaves, shoot weight, number of hands and bunch weight. In the case of number of fingers the difference was marginal only. Differences between generations were significant in the case of height, number of hands, number of fingers and bunch weight. Treatment x Generation interactions was not significant, indicating that the pattern of changes in the different generations was similar in both mycorrhizal and control plants. The nematode and mycorrhizal population

Table 43

Effect of VAM (Glomus mosseae) on the growth and yield of Banana cv. Njalipoovan in the field

CONTROL	Height (cm)	No. of leaves	No. of suckers	Bunch weight (kg)	No. of hands	No. of fingers	Shoot weight (kg)	Leaf area (Mean-cm^2)
1	312	26	8	5.0	6	69.5	15.80	2088.14
2	358	23	6	4.50	6	67	14.50	3206.79
3	409	21	8	5.50	6	62	15.50	4014.57
4	360	23	13	3.80	6	64	15.15	3209.87
5	359	25	8	6.20	6	85	18.70	4137.20
Mean	359.6	23.6	8.6	5.0	6	69.5	15.93	3331.31
MYCORRHIZAL								
1	414	26	12	7.95	8	92	22.80	4171.30
2	410	25	7	5.45	7	83	17.05	3771.70
3	403	24	3	5.80	9	92	21.65	4173.60
4	474	23	8	8.10	8	120	20.60	4546.02
5	421	23	8	6.62	7	98	21.50	5105.54
Mean	424.4	24.2	7.6	6.78	7.8	97	20.72	4353.63

Table 44

Nematode and mycorrhizal population associated with control and Glomus mosseae inoculated banana plants in the field

Treatment	Nematode population		Mycorrhizal population	
	soil (250 g)	Root	Resting spores (soil 50 g)	Root infection
Control	Meloidogyne incognita-88 Hoplolaimus seinhorsti-127 Helicotylenchus abunaamai-16 Xiphinema elongatum-10 Rotylenchulus reniformis-23 Diphtherophora sp.-2	M. incognita-198 H. seinhorsti-2	Glomus mosseae-17 Acaulospora bireticulata-57 Glomus fasciculatum-39 Gigaspora aurigloba-17 Unidentified spores-17	84%
Mycorrhizal	M. incognita - 22 H. seinhorsti- 167 X. elongatum-7 R. reniformis -62 Longidorus saginus - 2 Macroposthomia oachirai -1	M. incognita - 7 H. seinhorsti -1	G. mosseae -147 A. bireticulata -44 G. aurigloba- 17 G. pellucida - 17 Sclerocystis rubiformis-17	100%

Table 45

Growth parameters of Banana plants in control and mycorrhizal plots

(mean of 10 plants)

Character	Mycorrhizal plants	Control plants	difference	signififance
Height (cm)	532.3	476.1	56.2	NS
No. of leaves	29.4	27.8	1.6	NS
Total leaf area (m^2)	13.625	10.946	2.679	NS
Total shoot weight (kg)	32.97	24.89	5.08	Significant
Bunch:- No. of hands	9.6	8.3	1.3	Significant
No. of fingers	127.5	116.5	11.0	NS
Bunch weight (kg)	8.39	6.25	2.14	Significant

Table 46 (a)

Comparison of growth characters of 4 Generations of Banana Plants

A. Analysis of variance Table

Source	df	Height (m)		No. of leaves		Shoot wt(kg)		No. of hands		No. of fingers		Bunch wt(kg)	
		M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F
Treatment (A)	1	1.998	8.08**	7.225	5.12*	358.801	18.82**	11.556	7.80**	1593.9	3.33	41.616	20.10**
Generations(B)	3	2.640	10.67**	1.092	0.77	27.119	1.42	6.023	4.07**	2033.4	4.25*	12.481	6.03**
AB interaction	3	0.551	2.23	1.092	0.77	11.400	0.60	1.856	1.25	146.3	0.31	0.01	1.02
Error	32	0.247		1.412		19.067		1.481		478.1		2.03	

* significant at P=0.05 ** significant at P=0.01

(Table 46.....Contd)

Table 46 (b)

Comparison of growth characters of 4Generations of Banana Plants

B. Table of means

Particulars		Height (m)	No. of leaves	Shoot weight (kg)	No. of hands	No. of fingers	Bunch weight (kg)
Mycorrhizal		5.15	29.45	30.08	9.10	117.85	7.54
Control		4.70	28.60	24.09	8.03	105.23	5.50
Generation	1	4.89	29.0	28.91	9.50	122.60	7.14
	2	4.24	28.6	26.60	7.90	95.10	5.63
	3	5.11	29.1	27.70	8.90	124.30	7.78
	4	5.46	29.4	25.06	7.95	104.15	5.53
Gen. mean		4.92	28.03	27.09	8.56	111.54	6.52
CV %		10.10	4.09	16.12	14.21	19.60	20.07
CD for Generation		0.454	NS	NS	1.11	19.97	1.30

associated with each plant of the six different crops in the HDMSCS plot were assessed and are given in Tables 47 to 58.

There was marked reduction in the nematode population in mycorrhizal plants of all crops when compared to that of control plants. The results in the population assessment of nematodes in root and soil showed that mycorrhizal inoculation at the time of nursery raising was very effective in reducing the nematode infestation especially the population of M. incognita in the roots of banana and pepper. Nursery inoculation of mycorrhizae to the above said crops proved to improve the growth of the plants in the field and helped to reduce nematode infestation. Mycorrhizal infection and corresponding growth improvement was more in the case of plants grown in mycorrhizal plot. But plants in the control plot also developed mycorrhizal infection from the naturally occurring field population. In coconut there was 24, 45, 6 and 106 per cent increase over control in height, girth, number of leaves and total leaf area respectively after three years. In arecanut, there was only marginal difference in growth characters of mycorrhizal plants. But in the case of cacao and clove the plants in the mycorrhizal plot had significant difference in growth parameters. After three years the percentage increase in shoot length and number of leaves was 138 and 127 in cacao and 272 and 203 in clove over control respectively. The results showed that colonization of VAM in the nursery stage improved growth characters of the above mentioned crops. Three years after planting in the field, roots of all the respective six crops in the

Table 47

Nematode population associated with the control and Mycorrhizal Banana plants in the HIMSCS plot

	Nematode population	
	Soil (250 g)	Root (50 g)
Control	Meloidogyne incognita - 88 Hoplolaimus seinhorsti - 127 Helicotylenchus abunaamai- 6 Xiphinema elongatum - 10 Rotylenchulus reniformis - 3 Diphtherophora sp. - 2	M. incognita - 198 H. seinhorsti - 2 H. abunaamai - 6
Mycorrhizal	M. incognita - 22 H. seinhorsti - 167 X. elongatum - 7 R. reniformis- 62 Longidorus saginus - 2 Macroposthonia oachirai - 1	M. incognita - 7 H. seinhorsti - 1

Table 48

VA Mycorrhizal population associated with the control and mycorrhizal Banana plants in the HDMSCS plot

	Resting spores (50 g soil)	Root infection (per cent)
Control	G. mosseae - 17 G. fasciculatum - 39 A. bireticulata - 57 G. aurigloba - 17 Unidentified spore type- 17	84
Mycorrhizal	G. mosseae - 147 A. bireticulata - 44 G. aurigloba - 17 G. pellucida - 17 S. rubiformis - 17	100

Table 49

Nematode population associated with control and mycorrhizal coconut seedlings in theHDMSCS plot

	Nematode population	
	Soil (250 g)	Root (50 g)
Control	*Aphelenchoides* sp. - 1	*R. similis* - 130
	Ditylenchus sp. - 2	*H. seinhorsti* - 3
	Ecphyadophora teres - 1	*Ditylenchus* sp. - 2
	Epicharinema keralense - 1	
	Helicotylenchus abunaamai - 1	
	Hoplolaimus seinhorsti - 3	
	Pratylenchus zeae - 2	
	Radopholus similis - 13	
	Tylenchus sp. - 2	
	Xiphinema elongatum - 1	
Mycorrhizal	*Aphelenchoides* sp. - 2	*R. similis* - 29
	Ditylenchus sp. - 1	*H. seinhorsti* - 3
	Dolichodorus pulvinus - 1	
	E. keralense - 3	
	H. abunaamai - 2	
	H. seinhorsti - 3	
	P. zeae - 3	
	R. similis - 10	
	R. reniformis - 22	
	Tylenchorhynchus sp. - 4	

Table 50

VA mycorrhizal population associated with control and mycorrhizal coconut seedlings in the HDMSCS plot

	Resting spores (50 g soil)	Root infection (per cent)
Control	G. mosseae - 44	
	G. macrocarpum - 67	
	A. bireticulata - 47	17
	S. rubiformis - 57	
Mycorrhizal	G. mosseae - 67	
	G. macrocarpum -159	
	A. bireticulata - 67	
	S. rubiformis - 33	
	S. coremioides - 17	41
	G. nigra - 17	
	G. pellucida - 17	
	G. auriglobe - 17	

Table 51

Nematode population associated with control and mycorrhizal pepper plants in the HDMSCS plot

	Nematode population	
	Soil (250 g)	Root (10 g)
Control	*H. seinhorsti* - 38	*Meloidogyne incognita* - 206
	Meloidogyne sp. - 121	
	Xiphinema sp. - 2	
Mycorrhizal	*Hoplolaimus* sp. -11	*M. incognita* - 53
	Meloidogyne sp.- 18	
	Xiphinema sp. - 4	

Table 52

VA mycorrhizal population associated with control and mycorrhizal pepper plants in the HDMSCS plot

	Resting spores (50 g soil)	Root infection (%)
Control	A. bireticulata - 346	
	G. macrocarpum - 45	30 %
	G. fasciculatum - 50	
Mycorrhizal	A. bireticulata - 133	
	G. fasciculatum - 75	
	G. macrocarpum - 75	
	G. mosseae - 24	60 %
	G. aurigloba- 17	
	G. pallidum - 17	
	S. rubiformis - 83	
	Unidentified Spore type - 17	

Table 53

Nematode population associated with control and mycorrhizal Arecanut seedlings in HDMSCS plot

	Nematode population	
	Soil (250 g)	Root (50 g)
Control	*Meloidogyne* sp. - 135	*M. incognita* - 285
	Hoplolaimus sp. - 32	
	Xiphinema sp. - 2	
	R. reniformis - 31	
	Diphtherophora sp. - 2	
Mycorrhizal	*Meloidogyne* sp. - 59	*Aphelenchus* sp. - 36
	Hoplolaimus sp. - 8	*M. incognita* - 4
	Xiphinema sp. - 4	
	Helicotylenchus sp. - 16	
	Trichodorus sp. - 5	

Table 54

VA mycorrhizal population associated with control and mycorrhizal Arecanut seedlings in HDMSCS plot

	Resting spores (50 g soil)	Root infection (%)
Control	G. fasciculatum - 165	
	G. macrocarpum - 66	
	G. nigra - 17	
	S. rubiformis - 50	52 %
	A. bireticulata - 91	
	Unidentified spore type - 17	
Mycorrhizal	G. mossea - 169	
	A. bireticulata - 82	
	S. rubiformis - 50	
	G. fasciculatum - 88	77 %
	G. pellucida - 17	
	Unidentified spore type - 50	

Table 55

Nematode population associated with control and mycorrhizal clove plants in the HDMSCS plot

	Nematode population	
	Soil (250 g)	Root (10 g)
Control	Hoplolaimus sp. - 15 Xiphinema sp. - 3 Meloidogyne sp. - 7 Tylenchus sp. - 2 Helicotylenchus sp. - 3	Nil
Mycorrhizal	Hoplolaimus sp. - 15 Xiphinema sp. - 2 Helicotylenchus sp. - 7 Meloidogyne sp. - 5 R. reniformis - 14 Pratylenchus sp. - 5 Longidorus sp. - 2	Nil

Table 56

VA mycorrhizal population associated with control and mycorrhizal clove plants in the HDMSCS plot

	Resting spores (50 g soil)	Root infection (%)
Control	A. bireticulata - 96	
	G. fasciculatum - 42	40%
	G. macrocarpum - 42	
Mycorrhizal	A. bireticulata - 77	
	G. mosseae - 46	
	G. fasciculatum - 44	100%
	G. macrocarpum - 17	
	S. rubiformis - 67	

Table 57

Nematode population associated with control and mycorrhizal cacao plants in the HDMSCS plot

	Nematode population	
	Soil (250 g)	Root (10 g)
Control	*Helicotylenchus* sp. - 11	
	Hoplolaimus sp. - 24	
	Meloidogyne sp. - 9	*M. incognita* - 10
	Tylenchorhynchus sp. - 16	
	Xiphinema sp. - 4	
Mycorrhizal	*Hoplolaimus* sp. - 6	
	Meloidogyne sp. - 3	
	R. reniformis - 8	*M. incognita* - 2
	Xiphinema sp. - 7	

Table 58

VA mycorrhizal population associated with control and mycorrhizal **cacao** plants in the HDMSCS plot

	Resting spores (50 g soil)	Root infection (%)
Control	A. bireticulata - 73	
	G. macrocarpum - 142	
	G. fasciculatum - 116	70 %
	G. mosseae - 12	
	Gigaspora sp. - 17	
	S. rubiformis - 44	
Mycorrhizal	G. mosseae - 193	
	A. bireticulata - 150	
	S. rubiformis - 25	
	S. coremioides - 17	100 %
	G. fasciculatum - 25	
	Unidentified spore type - 17	

HDMSCS plot were collected, washed and mixed with sterile soil in earthern pots. Sorghum seeds were sown and raised up in these pots and used as trap plants for the isolation of VAM from the roots. In addition to the inoculated VAM Glomus mosseae, the native VAMycorrhizae present in the roots were also identified (Table 59).

21. Studies on standardisation of mode, time and frequency of of inoculation and quantum of inoculum in nursery

Two experiments were carried out in the coconut nursery in CPCRI Campus, using WCT seedlings raised in sandy loam soil as experimental seedlings. The experiments were aimed at standardising the quantum of inoculum and the mode, time and frequency of VAM inoculation in coconut nursery.

Experiment - 1

Coconut (WCT) seedlings growing in three rows of the same bed in the nursery were selected for the trial. Three groups of seedlings, consisting of 18 seedlings each were treated with VAM inoculum once in the first group, twice in the second group and thrice in the third group of seedlings. Another group of 18 seedlings in a separate bed was selected and retained as control. The VAM inoculum consisted of G. mosseae (100 g infested soil and root from the culture pot ranging from 1,000 - 1,200 spores). The first application of inoculum was given when the sprouts attained a plumule height of ½-1". The second inoculation was given after three months followed by the third inoculation after the next three months.

Table 59

VA mycorrhizae isolated from the roots of control and mycorrhizal plants in the HDMSCS plot - three years after planting

Crop	VAM colonised in the HDMSCS plants	
	VAM	
	Mycorrhizal	Non mycorrhizal
Banana	A. bireticulata, G. mosseae and two unidentified spore types.	A. bireticulata, G. mosseae.
Coconut	A. bireticulata, G. mosseae, G. macrocarpum.	A. bireticulata, G. mosseae, G. fasciculatum.
Arecanut	A. bireticulata, G. mosseae, Gigaspora nigra.	A. bireticulata, G. mosseae, G. fasciculatum.
Clove	G. mosseae	A. bireticulata.
Pepper	A. bireticulata, G. mosseae, G. fasciculatum.	A. bireticulata, G. mosseae, G. macrocarpum.
Cacao	A. bireticulata, G. mosseae and unidentified spore type.	A. bireticulata, G. fasciculatum, G. mosseae, G. macrocarpum.

The VAM resting spores encountered in the nursery bed prior to VAM application were A. bireticulata, S. rubiformis, Gigaspora sp., and Glomus macrocarpum and the nematode identified from the pre-treatment bed were Helicotylenchus abunaamai and Pratylenchus zeae. Growth parameters of the control and experimental seedlings prior to the second application were recorded (Table 60a-60d). Three months after the first inoculation fifty gram soil each, from the soil around the roots of the seedlings in the beds of above mentioned treatments were taken. 50 g soil from the control bed was also processed. The VA mycorrhizal species encountered in the different nursery beds were identified as follows.

Single application bed :

G. mosseae - 484, A. bireticulata - 150, Gigaspora sp. - 17, S. rubiformis - 17.

Double application bed :

G. mosseae - 166, S. rubiformis - 17, A. bireticulata - 33.

Triple application bed :

G. mosseae - 117 and A. bireticulata - 83.

Control bed

G. macrocarpum - 17, S. rubiformis - 17, A. bireticulata - 167, S. coremioides - 17.

The percentage root infection was 5 for the seedlings that received single dose of inoculum, 10 for seedlings that received double dose of inoculum and 10 for seedlings that received triple dose of VAM inoculum. The root infection in the

Table 60 (a)

Measurements of nursery coconut seedlings prior to second application of inoculum in the Triple application bed

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	9	57	3
2	10	46	3
3	10	38	2
4	11	42	2
5	8	28	3
6	9	33	2
7	9	67	3
8	9	38	3
9	8	54	4
10	8	51	3
11	9	41	3
12	10	39	4
13	9	40	3
14	8	46	3
15	9	48	3
16	8	34	3
17	9	38	3
18	8	49	3
Mean	8.9	43.94	2.94

Table 60 (Contd.....)

Table 60 (b)

Growth characters of the nursery coconut seedlings in the Double application bed –

(prior to the second application of inoculum)

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	9	63	3
2	10	55	3
3	9	54	3
4	7	52	3
5	8	49	2
6	8	28	4
7	9	44	2
8	8	40	3
9	9	36	4
10	9	49	3
11	9	53	3
12	9	34	4
13	8	36	3
14	9	50	3
15	8	40	3
16	8	47	3
17	8	32	3
18	7	25	2
Mean	8.4	43.72	3

Table 60 (Contd.....)

Table 60 (c)

Growth characters of nursery coconut seedlings in the Single application bed-

(prior to the second application of inoculum in other beds)

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	8	68	2
2	8	31	2
3	8	50	2
4	8	50	2
5	9	52	3
6	9	51	2
7	9	42	3
8	8	39	3
9	8	38	4
10	8	54	3
11	8	48	3
12	8	45	3
13	8	43	3
14	7	49	3
15	8	35	2
16	8	47	3
17	9	52	3
18	9	47	3
Mean	8.2	46.72	2.72

Table 60 (Contd.....)

Table 60 (d)

Growth characters of the nursery coconut seedlings in the Control bed (prior to the second application of inoculum in other beds)

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	9	23	2
2	8	35	3
3	8	38	2
4	8	47	3
5	9	42	3
6	9	66	4
7	9	37	3
8	9	55	4
9	8	45	4
10	9	50	2
11	9	50	3
12	10	51	3
13	9	51	3
14	8	40	3
15	9	51	3
16	9	51	3
17	8	39	3
18	9	59	3
Mean	8.7	46.1	3

seedlings of the control bed was four.

Three months after the first treatment, second application of G. mosseae inoculum (100 g soil + root) was given to the second and third set of seedlings consisting of 18 seedlings each. The first set of 18 seedlings in the single application bed was excluded from further VAM application.

The third application of the inoculum was given three months after the second application. The third quantum of inoculum was given only to the third set of 18 seedlings in the triple application bed where as the double and single application bed were left untreated. Growth parameters of the seedlings in single, double and triple application bed and control bed were recorded prior to the third application (Table 61 (a) - 61 (d)). The nematode and VA mycorrhizal population encountered in the soil and roots of the seedlings in the different beds were also assessed. The soil nematode population identified from the various treatments were as follows.

Control bed :

Hoplolaimus seinhorsti - 1, Helicotylenchus abunaamai - 7, Trichodorus - 1, R. similis - 10, Longidorus saginus - 1, Pratylenchus zeae - 3.

Single application bed :

Xiphinema elongatum - 2, Longidorus saginus - 1, Criconemoides - 1, Pratylenchus zeae - 3.

Double application bed :

Longidorus saginus - 1, Pratylenchus zeae - 1.

Table 61 (a)

Growth characters of nursery coconut seedlings in the --

Single application bed

(prior to the third application of inoculum)

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	10	79	5
2	9	74	5
3	10	109	5
4	10	104	4
5	11	110	5
6	12	104	5
7	10	70	4
8	10	90	5
9	10	84	4
10	10	76	4
11	9	97	4
12	9	72	4
13	10	78	6
14	10	74	5
15	10	81	5
16	11	87	6
17	11	83	6
18	11	110	5
Mean	10.17	87.88	4.8

Table 61 (Contd.....)

Table 61 (b)

Growth characters of nursery coconut seedlings in the Double application bed-

ior to the third application of inoculum in the triple application bed

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	11	108	6
2	12	118	4
3	9	88	4
4	10	110	5
5	9	99	4
6	9	80	3
7	9	55	3
8	10	76	5
9	10	89	5
10	9	88	5
11	11	111	5
12	10	93	5
13	9	59	5
14	10	83	7
15	10	70	5
16	10	80	5
17	9	48	4
18	10	80	6
Mean	9.83	88.05	4.78

Table 61 (Contd.....)

Table 61 (c)

Growth characters of nursery coconut seedlings in the Triple application bed -- prior to the third application of inoculum

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	11	99	4
2	12	104	5
3	10	75	5
4	11	122	5
5	12	98	4
6	11	82	5
7	11	121	5
8	10	92	5
9	10	98	5
10	11	89	5
11	9	87	4
12	10	88	5
13	10	82	5
14	9	85	4
15	11	57	5
16	10	97	5
17	10	68	5
18	6	82	3
Mean	10.22	90.33	4.67

Table 61 (Contd.....)

Table 61 (d)

Measurements of coconut seedlings in the Control bed

(prior to the third application of inoculum in other beds)

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	9	66	5
2	10	80	4
3	9	73	4
4	9	97	5
5	9	97	5
6	10	102	6
7	10	70	4
8	10	107	5
9	12	89	5
10	10	54	5
11	9	91	4
12	10	94	5
13	9	61	4
14	10	87	5
15	11	78	5
16	11	82	5
17	11	85	6
18	11	98	6
Mean	10	83.94	4.88

Triple application bed :

Longidorus saginus - 1, Xiphinema elongatum - 1.

The VA mycorrhizal root infection was 17, 28, 28 and 10 in seedlings grown in single, double and triple applicatio and control bed respectively. The VA mycorrhizae present in the different beds were identified as follows.

Single application bed :

G. mosseae - 133, A. bireticulata - 67.

Double application bed :

G. mosseae - 166

Triple application bed :

G. mosseae - 183

Control bed :

G. macrocarpum - 50, A. bireticulata - 33.

Growth parameters prior to the uprooting of all the seedlings were also recorded (Table 62 (a) - 62 (d) . The VA mycorrhizal infection in the roots of the seedlings grown in control, single, double and triple application beds were 15, 45, 54, and 62 per cent respectively. The resting spores recorded from the nursery beds of various treatments were

Control bed :

G. fasciculatum - 17, G. macrocarpum - 50, Gigaspora sp. - 17, S. rubiformis - 17.

Single application bed :

G. mosseae - 33, Gigaspora sp, - 17

Double application bed :

G. mosseae - 183, A. bireticulata - 17.

Table 62 (a)

Growth parameters of nursery coconut seedlings prior to uprooting- Triple application bed

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	14	118	7
2	17	149	7
3	12	123	7
4	15	139	6
5	14	147	7
6	12	126	7
7	12	115	7
8	12	131	7
9	12	125	6
10	14	128	6
11	15	126	8
12	13	115	6
13	15	133	7
14	14	119	7
15	14	118	7
16	11	113	7
17	17	128	8
18	13	116	6
Mean	13.66	126.10	6.78

Table 62 (Contd.....)

Table 62 (b)

Growth characters of nursery coconut seedlings in the Double application bed prior to uprooting

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	13	129	6
2	16	141	7
3	14	226	6
4	13	156	8
5	15	132	6
6	13	122	7
7	15	133	7
8	14	157	6
9	15	128	7
10	13	114	7
11	16	120	6
12	13	93	5
13	14	110	8
14	14	145	6
15	14	120	6
16	16	101	8
17	16	100	7
18	13	97	6
Mean	14.39	123.66	6.66

Table 62 (Contd.....)

Table 62 (c)

Growth characters of nursery coconut seedlings in the Single application bed (prior to uprooting)

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	14	93	6
2	13	119	7
3	14	139	6
4	14	127	5
5	15	148	6
6	15	132	6
7	15	152	7
8	15	115	6
9	15	128	6
10	14	127	7
11	15	131	8
12	16	130	7
13	14	129	5
14	14	103	7
15	15	102	6
16	15	84	5
17	15	130	6
18	14	118	6
Mean	14.56	122.61	6.61

Table 62 (Contd.....)

Table 62 (d)

Growth characters of nursery coconut seedlings in the Control bed prior to uprooting

Sl. No.	Girth (cm)	Height (cm)	No. of leaves
1	13	98	8
2	12	115	5
3	12	117	5
4	15	123	6
5	15	126	6
6	14	109	6
7	13	106	5
8	14	128	7
9	14	126	6
10	13	116	5
11	14	110	6
12	12	129	5
13	13	123	6
14	15	134	7
15	16	140	6
16	14	118	6
17	14	102	7
18	14	117	6
Mean	13.75	118.70	6

Triple application bed :

G. mosseae - 183, A. bireticulata - 33.

The nematode population in the soil and roots of seedlings pertaining to each treatment were also assessed. The roots of the seedlings in the control and single application bed yielded R. similis and P. zeae respectively, the roots of second and triple application seedlings did not yield any nematode population. Soil nematodes in the control bed were R. similis - 12, H. abunaamai - 22, and P. zeae - 12 and samples from the single application bed yielded only two numbers Pratylenchus zeae. The soil samples from the second and third application beds did not yield any nematode. R. similis infestation was noticed in other beds in the nursery. There was gradual increase in the leaf area and height of the seedlings from the single application bed to the bed where three applications of the inoculum was given where as the number of leaves in all the three groups of seedlings remained almost same (Table 63).

Experiemnt - 2

In order to study the influence of varying quantum of VAM inoculum and the degree of VAM colonisation in roots and in turn their ability in imparting resistance to burrowing nematode infestation was studied in a nursery trial. Coconut seedlings (WCT) growing in different beds in sandy loam soil in the CPCRI nursery at Kayangulam were selected for the experiment. The treatments were

Table 63

Effect of VAM application on the growth of coconut seedlings in the nursery

Treatments	Height (cm)	Girth (cm)	No. of Leaves	Leaf area (cm^2)
Single application	122.61	14.56	7	3460.67
Double application	123.66	14.39	7	3775.54
Triple application	126.10	13.66	7	4468.3
Control	118.70	13.75	6	3386.46

1. G. mosseae (50 g soil & root)
2. G. mosseae (100g soil & root)
3. G. mosseae (200g soil & root)
4. Mixed VAM inoculum (50 g soil & root)
5. Mixed VAM inoculum (100g soil & root)
6. Mixed VAM inoculum (200g soil & root)
7. Control without VAM inoculation

Each treatment consisted of 30 seedlings growing in three rows on the same bed. The VAM mixture used as inoculum consisted of G. mosseae, G. fasciculatum, G. versiforme, A. bireticulata and S. rubiformis. VA mycorrhizal and nematode population in the soil and root prior to VAM inoculation were assessed. 50 g soil from the nursery beds prior to VAM inoculation were processed for VA mycorrhizal spore recovery. The spores encountered were A. bireticulata - 33, Gigaspora sp. - 17, G. fasciculatum - 17, G. macrocarpum - 17, G. mosseae - 17 and S. rubiformis - 33 and the nematodes present in the nursery beds were Helicotylenchus abunaamai and Pratylenchus zeae. The first inoculation of VAM was given when the seedlings reached a height of 4". The second inoculation was carried out after three months. Growth characters of the seedlings viz. height, girth, number of leaves, lamina length lamina breadth and leaf area were recorded. The nematode and mycorrhizal population in the root and soil were estimated prior to the first inoculation of VAM and six months after inoculation (Table 64). Soil from six different places in the same bed were drawn, mixed well and an aliquot of 50 g soil from this was processed for VA mycorrhizal spore

Table 64

Effect of G. mosseae alone and a mixture of different VAM on growth of coconut seedlings in the nursery

Table of means

Treatments	Height (cm)	No. of leaves	Girth (cm)	Leaf area (cm^2)
Control	128.20	5.90	12.90	4050.69
G. m - 50	151.93	6.00	13.63	4897.34
G. m - 100	156.40	6.37	14.90	5048.50
G. m - 200	152.23	5.83	13.20	5160.45
Mixed - 50	145.07	6.13	13.23	4875.74
Mixed - 100	149.39	6.50	15.07	5610.66
Mixed - 200	139.67	5.63	12.77	4306.04
Gen. mean	146.12	6.05	13.67	4849.90
F ratio	12.84**	4.41**	9.00**	6.98**
SE/Plot	14.65	0.79	1.71	1088.02
C.V. (%)	10.03	13.11	12.53	22.53
C.D.	7.41	0.40	0.87	550.61

** significant at P = 0.01

G. m - Glomus mosseae Mixed - Mixture of different VAM

estimation. Fine feeder roots were collected and processed for assessing VA mycorrhizal root infection. The resting spores recovered and percentage root infection corresponding to each bed were as follows.

G. mosseae (50 g bed)	- G. mosseae - 33 S. rubiformis - 17 40 % infection
G. mosseae (100 g bed)	- G. mosseae - 50 50 % infection
G. mosseae (200 g bed)	- G. mosseae - 50 30 % infection
VAM Mixture (50 g bed)	- G. mosseae - 17 A. bireticulata - 133 30 % infection
VAM Mixture (100 g bed)	- G. mosseae - 33 S. rubiformis 17 40 % infection
VAM Mixture (200g bed)	- A. bireticulata - 33 40 % infection
Control bed	- A. bireticulata - 17

Marked difference in height between the mycorrhizal inoculated and control seedlings was noticed. Maximum height was recorded in beds where 100 g of G. mosseae inoculum was given. The same result was observed in the experiment where VA mycorrhizal mixture was used as the inoculum. Maximum height was recorded in seedlings that received 100 g inoculum.

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SUMMARY

1. Standardised the sampling area for maximum recovery of resting spores of VAM in soil in the root zone of Coconut. Maximum resting spores of VAM occurred at a distance of one metre away from bole of the palm within a depth of 25- 100 cm.

2. To standardise the type of sieves to be used, soil samples were processed using sieves of different pore sizes (710 µ to 45 µ). Results showed that maximum resting spores were obtained on 200 mesh (75 µ) sieve.

3. Irrespective of age, all kinds of roots of coconut palm harboured mycorrhizae (hyphal infection and spores). Maximum per cent infection was noticed in fine feeder roots (1 mm thick)-yellowish to brown in colour.

4. A total of 270 coconut palms growing in different soil types viz., alluvial, clayey, forest, kari, laterite, sandy and sandy loam soil were sampled and the resting spores of different VA mycorrhizae viz. Acaulospora bireticulata, A. laevis, A. trappei, Gigaspora aurigloba, G. coralloidea, G. gilmorei, G. margarita, G. nigra, G. pellucida, Glomus fasciculatum, G. fuegianum, G. invermaium, G. macrocarpum, G. microcarpum, G. mosseae, G. pallidum, Sclerocystis clavispora, S. coremioides, S.microcarpum, S. rubiformis and S. sinuosa were recorded.

5. Cultures of Glomus fasciculatum, G. mosseae, G. versiforme, G. macrocarpum, Gigaspora gilmorei, Acaulospora

bireticulata and Slerocystis rubiformis are being maintained on coconut and sorghum.

6. The results of the interaction experiment with the VA mycorrhizae, Glomus mosseae and R. similis showed that prior establishment of VAM was found to amoeliorate the ill effects of R. similis on coconut seedlings. Seedlings that received mycorrhizae alone recorded maximum height and leaf area.

7. The interaction between the burrowing nematode, Radopholus similis and VA mycorrhizae viz. Glomus mosseae, G. fasciculatum, G. versiforme and Gigaspora coralloidea on coconut seedlings was studied under greenhouse conditions. Among the four mycorrhizae, G. mosseae enhanced maximum growth in the plants followed by G. coralloidea. On interaction with the burrowing nematode, G. coralloidea proved to be the best followed by G. fasciculatum.

8. The interaction experiment carried out with the local isolates of VAM from elite coconut palms viz. A. bireticulata, G. coralloidea, G. macrocarpum and S. rubiformis with burrowing nematode showed that A. bireticulata had the best effect on plant growth and nematode suppression.

9. When a mixture of seven VAM isolates from local elite palms was used against R. similis on coconut, maximum growth characters viz. height, girth, number of leaves, lamina length and breadth, root weight, maximum number of mycorrhizal restigg spores and root infection were recorded in seedlings inoculated

with VA mycorrhizae alone followed by the seedlings where the VAM was inoculated prior to nematode inoculation. Prior colonisation of VAM could reduce the nematode multiplication.

10. In the nematicidal trial, phorate proved to be the best nematicide with least deleterious effect on VAM colonization. The nematicides were applied @ 10 g a.i./ palm to ten palms each. Nematicides were applied twice a year for 4 years. The percentage root infection was 74, 29, 28 and 79 for Phorate, Ebufos, and Carbofuran treated and control plants respectively.

11. The population build up of VAM, Glomus mosseae and burrowing nematode, R.similis was studied under field conditions in an HDMSCS plot involving coconut, arecanut, banana, pepper and clove. The plot with an area of 800 sq.m. was divided into two plots viz. a mycorrhizal plot where mycorrhizal seedlings (G. mosseae inoculated) of all the above said crops were planted and a control plot where non-mycorrhizal seedlings were planted. Growth parameters viz. height, number of leaves, vine length in pepper, leaf area etc were recorded and the results revealed that prior colonization of G. mosseae in the mycorrhizal seedlings enhanced growth characters. There was also considerable reduction in the root and soil population of nematodes in the mycorrhizal seedlings. The local VAM colonised was isolated from the roots by using sorghum as bait plants. In addition to G. mosseae, the native VAM thus

colonized in the roots were identified as A. bireticulata, Gigaspora nigra, Glomus fasciculatum and G. macrocarpum. In the case of banana plants, there was marked difference in the bunch weight and other growth characters between the mycorrhizal and control plants. There was 18, 2.5, 34.7, 35.7, 30, 39.6 and 30 per cent increase in height, number of leaves, leaf area, bunch weight, number of hands, number of fingers and shoot weight respectively in the mycorrhizal banana plants when compared to that of control plants in the field. Final measurements of the plants after three years, showed that the per cent increase in shoot length and number of leaves in mycorrhizae (G. mosseae) colonized plants over control was 138 and 127 in cacao and 272 and 203 in clove respectively.

12. Healthy palms recorded 20-100% VAM root infection when compared to 0-100 % infection in the root (wilt) affected palms.

13. Studies on the seasonal variation of VA Mycorrhizal population associated with coconut palms showed that dry season was succeeded by maximum spore recovery and increased root-infection. During rainy season and in the succeeding one or two months, the percentage root-infection and resting spore recovery was less. The favourable season for VAM sampling is from January to April preferably in the month of April.

14. Introduction of VA mycorrhizae in the coconut nursery proved to enhance the growth of seedlings. There was gradual increase in the plant height and total leaf area with increase in the inoculum densities.

13. Results which can be exploited in Pilot or field scale :

Raising up of mycorrhizal seedlings in the nursery was found to be effective in the better establishment of the plants in the field. Mycorrhizal seedlings of Coconut, Arecanut, Pepper, Cloves, Banana and Cacao on transplantation into the field showed improved growth in terms of height, number of leaves, leaf area etc. Significant increase in the bunch weight was noticed in banana var. Njalipoovan by nursery inoculation of the VA mycorrhizae, Glomus mosseae. G. mosseae inoculation on bananawas found to be very effective in reducing the multiplication and gall indices of the root-knot nematode, Meloidogyne incognita. Mycorrhizal inoculation did not give complete control of the burrowing nematode, Radopholus similis but could reduce the multiplication and amoeliorate the ill effects of nematode infestation. Therefore VA mycorrhizal inoculation in nurseries can be practiced in transplanted crops.

14. Papers / Articles prepared / published :

Papers published

1. SOSAMMA. V.K., SOBHA. A.T., RACHEL. S. AND ROHINI IYER (1990). "Vesicular arbuscular mycorrhizae associated with coconut palms". Paper presented at the seminar on "Bioagents in Nematode management" July 13, 1990, IARI, New Delhi.

Papers prepared

1. Seasonal variation of VA mycorrhizal population associated with coconut palms in Kerala.
2. Effect of nematicides on VA mycorrhizae associated with coconut palms.
3. Effect of VA mycorrhizal inoculation on coconut seedlings in the nursery.
4. Interaction of burrowing nematode and VAM on coconut.
5. Interaction of the VAM, Glomus mosseae and burrowing / root-knot nematodes on various crops-- a field trial.
6. Standardisation of sampling zone and type of root for VA mycorrhizal estimation on coconut.

15. Suggestions for future lines of research :

1. Involvement of VAM with other biocontrol agents viz. Paecilomyces lilacinus and Pasteuria penetrans against nematodes.
2. Multiplication of VAM on various organic amendments.

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Sosamma Varghese K.
Principal Investigator

Date : 4th May, 1994
Place: CPCRI (RS) Kayangulam

17. Signature :

Name :	Dr. Sosamma Varghese. K	Dr. P.K. Koshy
Designation:	Senior Scientist Nematology CPCRI (RS) Kayangulam, Krishnapuram-690 533 Kerala, India	Acting Joint Director CPCRI (RS) Kayangulam Krishnapuram-690 533 Kerala
	PRINCIPAL INVESTIGATOR	DIRECTOR OR IN CHARGE OF THE INSTITUTE / STATION

Date : 4 th May 1994.