GROWTH AND NUTRITION OF BLACK PEPPER AS INFLUENCED BY DECAYING LITTER MATERIALS IN SOIL

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **Growth and nutrition of black pepper as influenced by decaying litter materials in soil** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship fellow ship or other title of any University or Society

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Introduction

INTRODUCTION

Black pepper (Piper nigrum L) popularly known as the King of Spices is one of the most important spices grown in India Among the export oriented spices commercially cultivated in the country pepper has a unique position and maintained its identity till 1990 91 as the largest exporting crop both in quantity and value The average annual export earnings from black pepper during the last five years (1987 88 to 1991 92) is Rs 146 95 crores which is about 50 6% of the total earnings from spices (Anon 1992)

The major producers of black pepper besides India are Indonesia Malaysia Brazil Madagaskar Sri Lanka and Thailand As per the figures of 1990 the global area under the crop is 3 62 lakh hectares with an annual production of 2 01 lakh tonnes (Annon 1990)

In India the crop is grown in about 1 73 lakh ha with a production of 48 900 t which accounts for more than 47% of the area and 24% of production under the crop in the world (1990 91 statistics) Kerala accounts for nearly 97% of the total area in India (1 69 lakh ha) (Anon 1991)

Kerala being the native of the crop and its cultivation dates back to time immemorial it is paradoxical that the producti vity of the crop is very low (322 kg ha^{-1}) as against 2750 kg in Malaysia 1050 kg in Brazil and 449 kg in Indonesia (Anon 1990) Of the several reasons that are attributed to the low productivity of pepper vines in Kerala the nutritional factors assume a great importance

The crop is grown on plantation scale as well as in home steads in the State Invariably the vine is supported on live trees such as Erythrina indica Garuga pinnata Grevilea robusta or on any available crop tree Under such conditions the growth of the vine can be greatly influenced by the support tree in its neighbourhood through regulation of shade allelopathic effects competition for nutrients and water etc The soil milieu may also be altered by the decomposing litter originating from the support tree which in turn can influence the growth of the vine No information is currently available on the decay rates of fallen leaves from the support tree how the decomposition products influence the growth and nutrition of the vine etc This informat ion is necessary to explain the differential productivity of the vines trailed on different support trees In addition it will also reveal the relative effects of the litter materials and their decomposition products on the nutrition and growth of the vine The present study was therefore undertaken with the following objectives

To examine the effects of soil incorporation of leaf materials from support tree/intercrop on the growth and nutrition of black pepper vine

To determine the decomposition rates of leaves of these trees added to soil and

To assess the effects of litter decomposition on nutrient availability in the soil

Review of Literature

REVIEW OF LITERATURE

The growth of black pepper vine can be greatly influenced by the presence of the support tree in its immediate neighbourhood The soil milieu may also be altered by the decomposing litter originating from the support tree which in turn can influence the growth and nutrition of the vine The literature on aspects pertaining to the study are reviewed here under the following headings

1 Growth and nutrition of black pepper
2 Leaf litter decomposition
3 Allelopathic effects

1 Growth and nutrition of black pepper

In Sarawak experience and tradition led to the development of systems and methods of fertilizer application The jungle land which was cleared for pepper planting provided the raw material for the preparation of burnt earth (Harden and White, 1934 Bergman 1940) which served as a fertilizer for the vine The addition of burnt earth to soil had three fold effects viz (i) it altered the physical characteristics of the rooting medium (ii) it increased the pH value and (iii) it supplied the nutrients in a form ideally suited for uptake by the roots

De Waard and Sutton (1960) opined that the use of fertilizers by the farmers of Sarawak lowered the pH in the soil reduced the uptake of Ca and Mg and increased the K/Ca + Mg ratio in black pepper leaf They also attributed the dropping and yellowing of pepper growing in highly acid soils to Al toxicity Severe Mg deficiency and Al and Mn toxicity were also reported by Sim (1974) in Sarawak pepper gardens Addition of alkaline compounds to mounds prior to planting resulted in an increase in growth and earlier establishment of vines in Sarawak (De Waard 1978) Sangakkara (1989) investigated on the effect of pH of propagating medium on root and shoot growth of black pepper and found that greater root and shoot weights 70 days after planting were obtained on substrates with pH 7 8 and 8 1

Nybe (1986) could induce deficiency symptoms of macro and micronutrients by sand culture experiments in Kerala Deficiency symptoms of macronutrients except Ca and S were first manifested on the older leaves Symptoms of N deficiency were expressed as uniform yellowing followed by necrosis whereas purple to bronze yellow colour and ash coloured necrotic areas were the symptoms of P deficiency Potassium deficiency was characterized by tip and marginal necrosis which later progressed to the distal 2/3rd portion of the lamina Vegetative growth was considerably reduced due to deficiency of macro and micronutrients Ca P N and S showed profound influence on shoot growth Visual symptoms of deficiencies occured with a marked reduction in the foliar level of the concerned element

Sim (1974) found that leaf nutrient concentration had a better correlation with yield than soil nutrients The experiments conducted by Geetha (1990) on nutritional aspects of black pepper revealed that N P K Ca Mg and S application had influence on one or more of the growth parameters of bush pepper as well as vine pepper Calcium application improved the root characters markedly It was found that among the nutrients applied only N and S increased their concentration in the stem and leaf of bush pepper and vine pepper and treatments devoid of N produced typical N deficiency symptoms She observed considerable variability among black pepper varieties with respect to growth fertilizer P utilization nutrient concentration and nutrient uptake Leaf was found to be better accumulator for N K Ca S Fe and Mn in black pepper whereas P and Mg were more accumulated in the stem Concentration of Zn did not differ in both parts The order of nutrients removed by black pepper was K > N > Ca > Mg > P > S > Fe > Mn > Zn

De Waard (1969) also worked out the critical levels of N P K Ca and Mg as 2 70 0 10 2 00 1 00 and 0 20 per cent respectively below which deficiencies of the concerned elements were expected to occur Sushama et al (1982) reported that the first mature leaf counting from the tip of the lateral could be considered as the best for the foliar diagnosis of N P and K in pepper The period just prior to flushing (i e I ist weel of May) of pepper was the best suited for collection of leaf samples for foliar diagnoses (Sushama et al 1984) They also found significant positive correlation of yield with P and K of leaf whereas N content failed to establish significant correlation with yield

Geetha (1981) observed that the N P and K contents in the flowering laterals was higher during flowering and spike development (from June to November) but the same was found to decrease from November to December The Ca content was more in non flowering shoots from July to December She attributed low N and K content of flowering shoots during November December as one of the reasons for spike shedding in pepper

The foliar levels of N K Ca and Mg increased following fertilizer application in the rainy season Five nutrient elements P K Ca Mg and S were found to exert direct and indirect effects on yield of green pepper Of these P and K were found to be of greater importance in enhancing yield The period just prior to flushing was found to be the most suitable time for leaf sampling (Nybe et al 1989) The P indices of both the youngest matured and the next matured leaves gave significant correlation with pepper yield In case of youngest matured leaf highly significant correlation in the order of r 0 81** was obtained (Sadanandan and Rajagopal 1989) The studies also revealed that P index (P index $\frac{P}{N+P+K+Ca}$) value of 0 042 gave the highest yield of dry pepper and hence they suggested that P index can be used as a handy tool to find out the probable yield from any particular plantation

The nutrient removal by the variety Kutching (1729 vines/ha) was reported to be 252 04 kg N 31 75 kg P_2O_5 and 224 04 kg K_2O per hectare (De Waard 1964) Removal of inorganic nutri ents from soil by seventeen year old vines was reported by Sim (1971) as 233 kg N 39 kg P_2O_5 207 kg K_2O 30 kg MgO and 105 kg CaO per hectare Sim (1972) suspected toxicity of Mn to black pepper and identified the symptoms The quantity of micronutrients removed per vine of about one year-old was calculated as 365 mg Fe 281 mg Mn 194 mg Zn 89 mg Cu and 60 mg B (Sim 1973) Panniyur 1 is more nutrient exhaustive than Kalluvally and the order of contents of nutrients removed was N > K > Ca > Mg > P (Nagarajan and Pillai 1975) One hectare of pepper vines (numbering 1200) with an average yield of 1 kg dry pepper per vine removed 34 0 kg N 3 5 kg P_2O_5 and 32 0 kg K_2O for the production of berries in Panniyur Kerala (Pillai and Sasikumaran 1976) Based on this a manurial schedule of 100 g N 40 g P_2O_5 and 140 g K_2O per vine was recommended by them They also studied the N P K Ca and Mg levels in root stem leaf and spike of the four- year old Panniyur 1 pepper and reported that N and K were the highest and P the lowest in the leaves Annual exhaust of nutrients by a five year old vine through harvest of 1 284 kg dry pepper was 38 5 g N 36 7 g K 14 9 g Ca 13 7 g

Mg 2 2 g P 1 37 g S 218 mg Fe 155 mg Mn 28 mg Zn and 47 mg of Cu (Sankar 1985)

From an experiment to study the effect of organic and inorganic fertilizers on the yield of black pepper Raj (1972) observed that there was significant difference between NPK mixture with trace elements and organic manure Raj (1973) further observed that 12 oz of Urea and 16 oz of muriate of potash/plant/year gave the highest economic yield in sandy soils of Sarawak Based on a study in the variety Panniyur 1 Pillai et al (1979) concluded that higher levels of N adversely affected the yield and accordingly fixed 60 g N/vine/year as the ma imum limit The nutrient requirement of pepper vines trailed on dead standards was adequately met with 75 g N and 50 g P_2O_5/vine/year (Kumar and Cheeran 1981) Response of black pepper vine to lime application has been reported by Purseglove et al (1981)

De Waard (1979) referred to the key role played by nutrients especially K in the development of yellow leaf disease complex in black pepper in the islands of Bangka Indonesia and stated that a fertilizer mixture having 400 kg N 180 kg P 480 kg K 425 kg Ca and 112 kg Mg when applied to one hectare with appropriate mulching controlled the disease and gave an average yield of 2 0 2 5 kg dry berries per vine While studying the nutrition of slow wilt affected pepper vines Wahid et al (1982) found no difference in mi ronutrients level in the leaves although the healthy leaves had more K compared to the unhealthy Their studies also indicated N deficiency as a cause for the yellow leaf disease in black pepper Mustica et al (1988) could reduce the severity of yellow disease in black pepper by fertilizer (NPK 15 15 15) application of 250 g/vine/year and either aldicarb (50 g plant ^{1}) or manozeb (12 g plant ^{1}) or both

Purseglove et al (1981) recognised the necessity of micro nutrient application to black pepper in Sarawak and recommended 28 g trace elements per vine The mean yield of dry pepper in Southern Bahia ranged from 2883 kg ha ^{1} in the unfertilized plots to 7413 kg ha ^{1} in plots receiving N P K at 200 240 160 kg ha ^{1} + dolomite limestone at 1 t ha ^{1} + fritted micronutrients at 4 8 kg ha ^{1} (Chepote et al 1986)

Growth and yield of black pepper vine are influenced by the support tree Studies conducted on these aspects indicated that the growth and yield of the vine were much better when it was trailed on non living standards like teak pole than when trailed on live trees (Menon et al 1982 Kurian et al 1985 Anon 1987) Sankar et al (1988) observed that the nutrient uptake decreased when the vine was trailed on live trees According to them the two plant species namely the vine and the support tree are competing for nutrients and water as they share the same soil resources They also suggested that besides competitive inter action there was also evidence of support tree exerting an inhibitory effect on the vine

Wahid (1987) studied the effect of fertilizing and pruning the live supports on pepper plant yield in Indonesia and the best results were obtained with pruning the support trees three times a year and the application of 400 g fertilizer (12 N 12 P 17 K 2 Mg) per vine four times a year Mathai and Sastry (1988) recommended that support trees should be pruned during the pre flowering stage of black pepper vine which increase the light availability and produced greater leaf area and more compact canopy structure with shorter lateral shoots This allowed the vine to accumulate higher levels of metabolites which led to greater production of lateral shoots during the second flush more flower spikes a greater number of berries per vine and higher dry weight of berries per vine

Significant positive correlation between yield and leaf N was observed in case of black pepper (Panniyur 1) (Sadanandan et al 1991) Sadanandan (1992) observed that application of organic ammendments like neem cake at one ton per hectare besides the scheduled fertilizers resulted in significant increase in the availability of nutrients in the soil increased yield of pepper and restricted incidence of foot rot and slow decline of pepper

2 Leaf litter decomposition

Leaf litter incorporation in to the soil could be coordinated with periods of maximum nutrient demand by the crop based on the understanding of the rate of decomposition and nutrient release pattern The advent of Chemical farming apparently reduced the importance of this type of research in agri cultural ecosystem Some of the investigations on related aspects are reviewed here

2 1 Factors affecting decomposition

Decomposition is an oxidation process The rapidity with which a given substrate is oxidised will depend on its chemical composition and the physical and chemical conditions in the sorrounding environment (Donahue et al 1990) They reported that the maximum rate of decay of organic material takes place at 30 to 40°C In the range below optimum generally 5 to 30°C raising temperature accelarates plant residue decompositiion Above about 40°C the rapidity of decomposition declines except in those special circumstances where thermophilic decay is initiated Decay of major plant constituents is depressed as the supply of oxygen deminishes Moisture too must be adequate for decomposit ion to proceed Microorganisms grow readily in liquid media provided the oxygen supply is ample Most common microorganisms grow best at pH 6 8 but are severely inhibited below pH 4 5 and above pH 8 5 Nirogen is the key nutrient substance for microbial growth and hence for organic matter break down (Rai and Srivastava 1982 Donahue et al 1990 Kumar and Deepu 1992) Alexander (1976) reported that C N ratio of 20 1 or narrower have sufficient nitrogen to supply the decomposing microbes and also to release nitrogen for plant use He also observed that P mineralization begins when C P ratios are between 100 1 and 300 1

Melillo et al (1989) stated that LCI (Lignocellulose index) is the index of the plant materials susceptibility to microbial attack LCI is the ratio of lignin concentration in plant litter to the concentration of lignin plus acid soluble carbohydrates From their experiments they concluded that different leaf materials of different initial composition including different LCIs falling to the soil eventually reach a common chemistry with an LCI in the 0 7 to 0 8 range through the activities of the microbial community

2 2 Rate of decomposition and nutrient release

Consequent upon the decomposition of any organic matter added to soil the native soil organic matter also begins to decompose and in this process more quantities of nutrients are liberated for use by the plant this is so called priming action pointed out by Lohins (1926)

The experiments by Dalton et al (1952) point out that organic matter added to the soil as an ammendment is effective in increasing the availability of soil phosphate Easily decomposible organic matter is more effective in this regard than those organic substances that decompose slowly

A laboratory experiment for a period of 63 days was conducted by Datta and Goswami (1962) at IARI to study the decomposition of ^{14}C and ^{32}P tagged organic matter (oat and berssem tops) The results obtained with loss of carbon from added organic matter indicated that the decomposition of oat was virtually complete within 46 days but that of berseem continued upto 63 days the rate however decreased with time in both

Singh (1969) reported that generally 3 to 5 months are required for almost complete decomposition of leaf litter of important trees of tropical deciduous forests at Varanasi

Decomposition rates and changes in the nutrient content of needle and leaf litter were examined in Doughlas-fir Western hemlock Pacific silver fir and red alder ecosystem in Western Washington USA by Edmonds (1980) The patterns of loss of elements from litter bags after 2 yearss varied from ecosystem to ecosystem red alder (K > Mg > Ca > P > N > Mn) Douglas fir (K > P > Ca > Mg > Mn > N) Western hemlock (K > Ca > Mg > N > Mn > P) and Pacific silver fir (K > Mg > Ca > Mn > P > N)

Ojeniyi and Agbede (1980) observed a positive regression between coffee yield and soil organic C content in different Nigerian ecological zones The investigations by Pandey *et al* (1980) revealed that the decay rate constant (k) varied between 0 738 and 0 888 indicating a very rapid litter decomposition in tropical climate with marked dry and wet seasons

Aranguren *et al* (1982) studied nitrogen cycle of tropical perennial crops (cacao) under shade trees in northern Venezuela and found that litter on the soil surface contain from 24 kg N in November to 50 kg N ha^{1} in May Shade tree leaves made up 61% of the total N in the litter on the soil

The nutrient changes and release during decomposition of leaf litter in Himalaya oak conifer forest indicated that the total annual release of nutrients on the site through decomposition relative to the total input through litter fall amounted to 56% for N 83% Ca and 97% for water soluble compounds (Pandy and Singh 1984)

Baker and Attiwal (1985) studied the rates of loss of N P K Na Ca and Mg during decomposition of senescent foliage of *Eucalyptus obliqua* and *Pinus radiata* in the field using litter bag technique in Gippsland Victoria In pine litter N was immobilized for atleast two years after decomposition commenced but in the eucalyptus leaf litter there was a net release of N after one year About 20% of P was lost in the first three months after which there was a little change K and Na were characterised by rapid initial rates of loss followed by changes which were either weakly or not significantly correlated with loss of organic matter Ca and Mg were characterised by losses which were relatively closely associated with losses of OM

Das and Ramakrishnan (1985) pointed out that in case of *Pinus kesiya* plantations in N E India the dry weight loss of decomposing litter for the 1st year was about 37% The nutrients released in terms of percentage of original nutrient mass with in first 12 months were 88% K 63% Ca 62% Mg 53% P and 32% N and after two years it was 98% K 90% Ca 89% Mg 87% P and 72% N

A study conducted at Maruteru (A P) to compare the *Glyricidia* leaf *Ipomea* leaf and paddy straw incorporation as a supplemental sources of nitrogen to rice indicated that highest grain yield (53 2 q ha^{1}) with *Ipomea* leaf at 5 t ha^{1} coupled with application of N in chemical form at active tillering and panicle initiation stages and it was significantly superior to all other treatments The conspicuous effect on yield due to ipomea (5 t/ha) was attributed to the fact that those leaves are more succulent (70% moisture) and contain more N (1 83%) The inferiority of both glyricidia and paddy straw was attributed to be due to low N (1 05 and 0 54% respectively) (Raju *et al* 1987)

The study by Sharma and Ambasht (1987) onn *Alnus nephalensis* plantation in the eastern Himalaya showed that at each sampling nutrients (N P K and Ca) remaining in decomposing litter decreased significantly The initial percentage labile fraction of nutrients declined in the sequence K > P > Ca > N Half life ($t_{\frac{1}{2}}$) was short for K (2 4 months) and phosphorus (2 7 months) and approximately 10 times longer for nitrogen (21 months)

Incorporation of *Lantena camera* *Eupatorium adenophorum* and wheat straw each at 5 t/ha on dry weight basis resulted in 38 2 19 5 and 6 5% increase in grain yield of transplanted rice respectively over control (Thakur and Singh 1987) Maize sorghum and groundnut grown in pots on forest influenced soil produced higher dry matter than on ordinary field soil (Verinumbe 1987)

Arias (1988) reported that in Colombia the half life of litter was 60 days for *Albizia carbonaria* 80 days for *Gliricidia sepium* and *Sesbania grandiflora* 120 days for *Erythrina* sp and *Cajanus cajan* and 170 days for *Cassia grandis* and over 80% of nitrogen phosphorus and potassium were released in to the soil within 170 days

Beer (1988) studied litter production and nutrient cycling in coffee and cacao plantation with shade trees at Costa Rice and reported that the litter fall has potential importance for the cycling of N P K Ca and Mg since the litter inputs frequently exceeds nutrient inputs from inorganic fertilizers even when applied at highest recommended levels

Young (1989) observed that the maize and sorghum in pot samples from soils under trees in northern Nigeria grow two to three times faster than in soil without trees He also reported that in Tlaxcala Mexico (subhumid climate) trees with intercropped maize influenced soil properties to a 6 10 m radius under Prunus capuli and Juniperus sp N was 1 5 3 times higher under trees available phosphorus 4-7 times potassium 1 5 3 times and Ca Mg carbon and CEC were also increased Leucaena Gliricidia and Cassia prunings released most nitrogen within 60 days of applicat ion to soil Leucaena decomposed mainly within 40 days

The leaf litter decomposition and nutrient release pattern in plantations of Shorea robusta (Sal) and Eucalyptus camaldulensis growing on similar eco climatic and edaphic conditions in Dun Valley indicated that the decomposition constant (k) was 0 878 and 1 547 respectively for a period of one year The rate of decomposition was fast during monsoon months Elemental mobility of the nutrients from decomposing soil litter was in the order of Mg > K > P > Ca > N whereas for eucalyptus it followed the order of K > Mg > P > Ca > N for 12 months duration (Bahuguna et al 1990) Murthy et al (1990) found that leaf meal incorporation in combination with fertilizer improved soil fertility

Prasad et al (1991) reported that incubation of tree leaves viz sal teak eucalyptus subabul and mixed with the soil for 12 months increased the available P K and exchangeable Ca and Na significantly In general the magnitude of nutrient availab ility increased with the increase in level of application of tree leaves

Litter production and decomposition dynamics in moist deciduous forests of the Western Ghats in Peninsular India was studied by Kumar and Deepu (1992) The time required for complete disappearance of the original biomass ranged from five to eight months Foliage nitrogen content and disturbance levels strongly influenced litter decaly rates and mineral nutrient release into the ecosystem

3 Allelopathic effects

Molish (1937) coined the term allelopathy to refer to bio-chemical interactions between all types of plants including micro organisms His discussion indicated that he meant the term to cover both detrimental and beneficial reciprocal biochemical interactions Rice (1974) modified the above definition and defined allelopathy as any direct or indirect harmful effect by one plant (including microorganism) on another through production of chemical compounds that escape in to the environment

Our increasing knowledge of the conditions underwhich certain crop residues cause allelopathic effects to subsequent crops will enable us to guard against such effects

McCalla and Duley (1949) suggested that the detrimental effects of crop resudues on subsequent crops might be due to a combination of toxins from the residues and from microorganisms that were caused to grow more profusely by substances in the residue

Lee and Monsi (1963) found a report by Banzan Kumazawa in a Japanese document some 300 years old that rain or dew washing the leaves of red pine (_Pinus densiflora_) is harmful to crops growing under the pine

Red clover (_Trifoloium pratense_) exhibits allelopathy against itself (Tamura _et al_ 1967 and 1969) These workers isolated nine inhibitory isoflavonoids or related compounds from tops of red clover Webb _et al_ (1967) found that _Grevilea robusta_ A Cunn does not regenerate in _G robusta_ plantations though other rain forests do They identified some water transferable factor as associated with the rhizosphere of this species in which anta gonistic microflora may be involved

Chang _et al_ (1969) concluded that clover sickness results from the exudation by red clover of isoflavonoids which decompose to phenolic compounds whi accumulate in soil to an inhibitory level

The importance of phenolic acids or allelopathic compounds caused Glass to conduct a series of investigation on effects of these compounds on ion uptake by barley *Hordeum vulgare* roots (Glass 1973 1974 Glass and Dunlop 1974 Glass 1975) All phenolic acids tested inhibited ^{32}P labelled phosphate uptake and the degree of inhibition correlated well with the lipid solubility of the compounds Potassium uptake was inhibited also by twelve different phenolic acids

Al Mousawi and Al Naib (1975) observed that leaf extracts decaying leaves and soil collected under *Eucalyptus* canopies inhibited seed germination and seedling growth of associated species

Chou and Lin (1976) found that aqueous extracts of decomposing rice residues in soil inhibited radicle growth of rice and lettuce seedlings and growth of rice plants Root initiation of hypocotyl cuttings of mung beans was also suppressed by extracts of decaying rice residues and extracts of paddy soil Chou and Patric (1976) identified 18 compounds in decomposing corn residues in soil which were phytotoxic in the lettuce seed bioassay

Fourteen phytotoxins from leaf litter and the soil in a low land forest community were isolated by Lodhi (1978) The accumulation of such phytotoxins corresponded with the amount of litter produced and the decaying rate These phytotoxins continued to influence the soil properties around the trees

Chou (1986) gave some examples of crops which are affected by (auto) allelopathic growth inhibition These crops include rice sugarcane clover crops in apple and peach orchards and conifers growing close to bamboo In 1986 Segwal reported that in pot trials with maize irrigation with leaf leachate of Grewia optiva through out the growth period increased the germination percentage and plant height as compared with water irrigation

In black pepper Geetha et al (1990) observed browning of the explants (shoot tips nodal and internodal segments) and media because of the phenolic oxidation However phenolic interference was low for leaves and roots

Materials and Methods

MATERIALS AND METHODS

The present investigation on the growth and nutrition of black pepper as influenced by decaying litter materials in soil was carried out at Radiotracer Laboratory College of Horticulture Vellanikkara which is located at an altitude of 22 25 m above MSL at latitude 10°31 N and longitude 76°10 E and enjoys typical humid warm climate The investigations reported here are concerned with three aspects

1 Effect of soil application of various leaf materials on the growth and nutrition of black pepper

2 Determination of rates of decomposition of various litter materials in soil and its effect on nutrient availability and

3 Estimation of rates of decomposition of leaf materials in the field

1 Effect of soil application of various leaf materials on growth and nutrition of black pepper

To study the effect of decomposition of leaf materials a pot culture experiment was conducted in the green house of the Radiotracer Laboratory from 25th July 1991 to 26th January 1992

1 1 Soil and planting material

Shifted lateritic soil (Oxisol) was used in the study Surface soil (0 25 cm depth) was collected and sieved through 2 mm mesh for use in the experiment Earthen pots of 35 cm height 25 cm diameter at the top and 20 cm diameter at the bottom (without drain holes) were filled with 4 kg soil per pot

1 2 Organic sources

Five organic sources (leaf materials) were tested in the experiment These were the leaves of *Coffea arabica* (coffee) *Erythrina indica* *Garuga pinnata* *Grevilea robusta* (silver oak) and leaf litter of *Piper nigrum* (black pepper) These were selected because of their practical significance The trees *Erythrina indica* *Garuga pinnata* and *Grevilea robusta* are used as support trees for the vine and hence decomposition of their litters can affect the vine growth Since the vine is grown mixed in coffee plantations coffee leaf was also included as one of the organic sources for the same reason The collected leaf materials were dried and choped into pieces of about 1 2 cm size before use

1 3 Treatment details

The experiment was laid out in completely randomised design There were sixteen treatments and each treatment was replicated thrice The treatments were

Sl No	Treatment notation	Organic source (leaf material)	Applied level* (per cent)
1	C_1	Coffee	1
2	C_2		2
3	C_3		3
4	E_1	Erythrina	1
5	E_2		2
6	E_3		3
7	G_1	Garuga	1
8	G_2		2
9	G_3		3
10	S_1	Silver oak	1
11	S_2		2
12	S_3		3
13	B_1	Black pepper	1
14	B_2		2
15	B_3		3
16	Control	Without any organic source	

* On dry matter basis with respect to quantity of soil

The dried and chopped leaf materials from the five plant species were incorporated into the soil in pots separately at rates of one two and three per cent of soil weight The pots were arranged randomly on concrete benches inside the green house

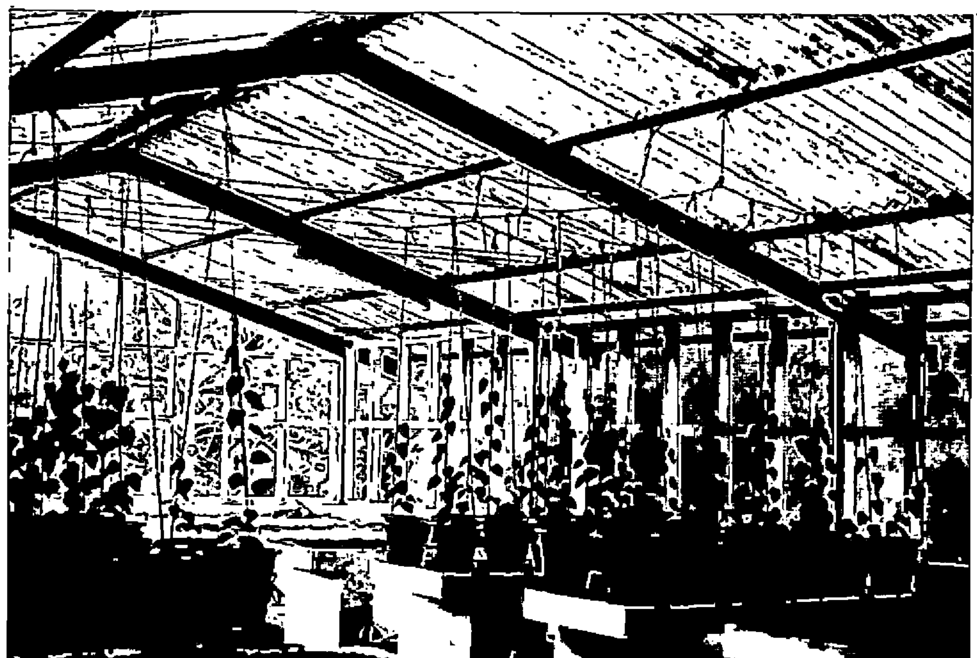
Rooted black pepper (var Panniyur 1) cuttings with two leaves were selected for planting in the pots After removing the polythene bag containing potting mixture in which the cuttings were raised (3-4 cuttings per bag) the cuttings were separated from each other and the roots were freed by adhering soil particles carefully by running water under a tap They were then planted to the pots containing soil and leaf material at the rate of one cutting per pot The planting was done on 25th July 1991

1 4 After-care of plants

The vines were taken care of as per the Package of Practice Recommendations of KAU (Anon 1989) The necessary plant protection measures were followed against attack from pests and diseases The vines also received uniform doses of N P and K at the rate of 100 50 and 100 kg ha^{-1} respectively in the second month after planting Each pot thus received 200 mg N 98 5 mg P_2O_5 and 192 mg K_2O Nitrogen was supplied through urea Phosphorus and potassium were supplied through analytical grade KH_2PO_4 and KCl respectively

The vine in each pot was trailed on coir rope suspended from the ceiling of the green house and tied around the neck of the pot (Plate 1) The vines were allowed to grow for six months before they were harvested on 26th January 1992

Plate 1 General view of the pot culture experiment



1 5 Observations

1 5 1 Dry matter production

During harvest the shoot portion was separated into stem and leaf The roots were carefully recovered from soil by removing the adhering soil particles using running water The dry weight of leaves stem and roots on per plant basis were recorded separately after drying in a cross flow air oven at 70°C + 2° till constant weights were obtained

1 5 2 Plant analysis

The dried leaves and stem samples were ground in a Wiley mill fitted with stainless steel blades and passed through 40 mesh sieve The samples were analysed for macro and micronutrients as detailed below

Total N was estimated by Kjeldahl method (Jackson 1958) For the analysis of other elements diacid extracts were prepared by digesting 1 g of the sample in 15 ml of 2 1 concentrated nitric perchloric acid mixture (Johnson and Ulrich 1959) Aliquots of the digests were taken for the analysis of total P K Ca Mg S Fe and Mn

Phosphorus was determined colorimetrically by vanadomolybdo phosphoric yellow colour method (Jackson 1958) The yellow colour was read in a spectrophotometer (Spectronic 20) at a wave length of 470 nm Potassium was estimated using flame photometer

(EEL make) Total Ca and Mg were determined by EDTA titration method (Jackson, 1958) Sulphur in the diacid digest was determined turbidimetrically following barium chloride method (Hart 1961) The turbidity was read using a spectrophotometer (Spectronic 20) at a wavelength of 490 nm Iron was estimated by KSCN method (Jackson 1958) and the colour was read at a wavelength of 490 nm using spectrophotometer (Spectronic-20) Manganese content of the diacid digest was determined using an atomic absorption spectrophotometer

1 5 3 Soil analysis

The initial soil used in the experiment and the soil samples collected from the pots at the time of harvest of black pepper crop were analysed for pH organic carbon available P exchange able K, Ca and Mg available S Fe and Mn The details of chemical analysis of soil are given in Table 1

Soil used in the experiment was also analysed for physical properties such as particle size distribution and water holding capacity Particle size distribution of the soil was found out by Hydrometer method (Piper 1942) Water holding capacity of the soil was determined based on the method of Keen and Raczkowski (1921) using Keen Raczkowski boxes

1 5 4 Nutrient uptake

The uptake of N P K, Ca Mg S Fe and Mn were

Table 1 Details of the methods used

Characteristic	Soil-solution ratio	Extraction period (min)	Extractant used
pH (H_2O)	1 2 5		
Organic carbon			
Available P	1 10	5	Bray I
Exchangeable K	1 10	30	N Ammonium acetate (pH 7)
Ca	1 10	30	
Mg	1 10	30	
Available S	1 10	30	KH_2PO_4 with 50 ppm P
Fe	1 10	15	(Double acid) 0 05 N HCl + 0 025N H_2SO_4
Mn	1 10	15	

for chemical analysis of the soil

Method of estimation	Instrument used	References
Direct reading	pH meter	Jackson (1958)
Walkley-Black	Titrimetric	Jackson (1958)
Ascorbic acid blue	Spectrophoto meter	Watanabe and Olsen 1965
Direct reading after dilution	Flame photo meter	Jackson (1958)
EDTA method	Titrimetric	Jackson (1958)
EDTA method	Titrimetric	Jackson (1958)
Turbidimetric	Spectrophoto meter	Fox *et al* (1964) and Jones *et al* (1972)
KSCN method	Spectrophoto meter	Jackson (1958)
Direct reading after dilution	Atomic absorption Spectrophoto-meter	Page (1982)

computed from the values of concentration of the nutrients in the above ground parts i e leaf and stem and their dry weights

1 6 Statistical analysis

The statistical analysis of the data was done using the methods suggested by Panse and Sukhatme (1985)

2 Determination of rates of decomposition of various litter materials in soil and its effect on nutrient availability

2 1 Materials

The lateritic soil collected for pot culture was used in this experiment The leaf materials (coffee Erythrina indica Garuga pinnata silver oak and black pepper) collected for pot culture experiment were powdered in a Wiley mill and seived through 40 mesh prior to use in the incubation experiment

2 2 Incubation experiment

Batch incubation experiment was conducted in the laboratory using the five organic sources each at three levels There were 15 treatments with two replications for each treatment The experi ment was laid as completely randomised design The details of the treatments are

Sl No	Treatment notation	Organic source (leaf material)	Applied level* (per cent)
1	C_1	Coffee	1
2	C_2		2
3	C_3		3
4	E_1	Erythrina	1
5	E_2		2
6	E_3		3
7	G_1	Garuga	1
8	G_2		2
9	G_3		3
10	S_1	Silver oak	1
11	S_2		2
12	S_3		3
13	B_1	Black pepper	1
14	B_2		2
15	B_3		3

* On dry matter basis with respect to quantity of soil

The powdered leaf material was mixed well with 100 g soil (2 mm sieved) in plastic containers of 8 cm height and 6 cm diameter These soils were incubated at 60% WHC for different intervals of time

2 3 Chemical analysis

At each interval i e zero, 15 30 60 90 and 120 d of incubation the organic carbon loss due to decomposition was assessed by determining the organic carbon content of soil by Walkley Black method (Jackson 1958) From the data so obtained the rates of decomposition of the organic sources were determined mathematically

The soil samples collected after a period of two months (60 d) of incubation were analysed chemically for the major and micronutrient availability The details of the chemical analysis of soil are given in Table 1 These samples were also analysed for E value (isotopically exchangeable P) based on isotope dilution technique (IAEA, 1976) following the equation

$$E_t = \frac{r_i}{r_f} \times {}^{31}P_f - {}^{31}P_i \quad (\mu g\ g^{-1}\ \text{soil})$$

where ${}^{31}P_i$ is the amount of ${}^{31}P$ in the initial solution given in ug P g^{-1} soil r_i and r_f are the count rates per unit volume of the initial and final ${}^{31}P$ solutions respectively and ${}^{31}P_f$ is the amount of ${}^{31}P$ in the final solution (ug P g^{-1} soil)

3 Estimation of rate of decomposition of leaf materials using litter bag technique

The five leaf materials (coffee *Erythrina indica* *Garuga pinnata* silver oak and black pepper) collected for pot culture experiment were used in this experiment

Litter decomposition studies were carried out in the field using the mesh bag technique described by Bocock and Gilbert (1957)

Ten grams of oven dried leaf of each species was transferred separately into 10 cm x 10 cm size nylon mesh bags (mesh size 2 mm) and the openings were closed firmly by stitching A total of 12 such bags were prepared for individual species These litter bags were then kept in field randomly at 5 cm depth in soil on 15th February 1992

3 1 Observations

At monthly intervals between 15th February 1992 and 15th August 1992 two litter bags of each species were recovered from the field The litter mass remaining in the bags were cleaned free of extraneous materials oven dried at 60°C for 48 h and dry weight determined

From the data so obtained the rates of decomposition of different leaf materials were calculated mathematically

Results

RESULTS

The data generated from the experiments in respect of the response of black pepper vine to applied organic sources changes in soil chemical characteristics and decomposition of the litter materials in soil are presented in this section

1 Biomass production in black pepper

The data pertaining to biomass production in terms of dry weights of leaf stem shoot and root are given in Table 2 The analyses of variance of the data are given in Appendix-1 Biomass production in black pepper was significantly increased following the incorporation of organic sources into the soil compared to the control vines which did not receive green manuring

1 1 Shoot production

Differences in leaf biomass were observed among the different levels of applied organic source Although there was significant increase in leaf production in plants receiving coffee leaves compared to the control vines at the highest level of application (3 per cent) a fall in leaf production was noticed The different rates of application of erythrina did not show significant differences among them although leaf production in the vines was significantly improved as compared to control A similar effect was noticed

Table 2 Dry matter production (g plant ^{1}) in black pepper vine as influenced by the application of various leaf materials

Organic source	Shoot			Root	Total
	Leaf	Stem	Total		
Coffee					
C_1	7 50	4 67	12 17	2 44	14 61
C_2	7 34	4 45	11 79	1 65	13 44
C_3	4 93	2 83	7 76	1 00	8 76
Erythrina					
E_1	6 60	3 35	9 95	2 39	12 34
E_2	8 67	5 13	13 80	2 47	16 27
E_3	7 23	4 21	11 44	1 56	13 00
Garuga					
G_1	4 72	2 90	7 62	1 26	8 88
G_2	6 88	4 72	11 60	2 05	13 65
G_3	9 35	5 73	15 08	2 51	17 59
Silver oak					
S_1	6 00	3 64	9 64	1 72	11 36
S_2	6 62	3 83	10 45	2 03	12 48
S_3	8 36	4 48	12 84	2 20	15 04
Black pepper					
B_1	8 76	5 11	13 87	2 64	16 51
B_2	8 82	6 43	15 25	2 31	17 56
B_3	6 76	3 87	10 63	1 76	12 39
Control	3 07	2 10	5 17	0 99	6 16
SEm±	0 81	0 61	1 37	0 42	1 75
CD (0 05)	2 34	1 76	3 95	NS	5 04

NS - Not significant

1 2 and 3 denote rates of application at 1 2 and 3 per cent respectively

in the case of application of leaves of black pepper With increasing rate of application of garuga leaf leaf production increased steadily and at the highest level (3 per cent) of application the leaf production in the vine increased to 9 35 g plant^{-1} This is the highest value obtained for leaf production Silver oak leaf application at 3 per cent level also increased leaf production in the vines

Stem biomass production followed more or less a similar trend as in leaf production (Table 2) Thus differences in stem growth were observed between the control vine and the vines receiving organic material Among the organic treatments, the lowest stem production (2 83 g plant^{-1}) was observed in vines receiving coffee leaves at the rate of 3 per cent while the highest (6 43 g plant^{-1}) value was recorded by the vines receiving black pepper leaves at the rate of 2 per cent

Total shoot biomass was significantly more in vines receiving organic amendment compared to control plants (Table 2) The general trend in total shoot biomass production was similar to that observed for leaf and stem in respect of the rate of application of different leaf materials The highest shoot dry matter (15 25 g plant^{-1}) was recorded for the vines receiving black pepper leaves at the rate of 2 per cent while the lowest among the treated vines (7 62 g plant^{-1}) was for the garuga leaf application at the rate of 1 per cent

1 2 Root production

Analysis of variance comparing the sixteen treatments did not show any significant difference in root production between control and organic sources as well as among the level of each organic source (Table 2 and Appendix 1) However when the data of control vines were compared against the rest of the treatments taken together significant difference in root production was observed

1 3 Total dry matter production

The total biomass production was considerably increased following the application of leaf materials (Table 2) The control vines had the poorest growth (6 16 g plant ^{1}) The growth of the vines receiving different organic amendments was influenced by the quantity of the applied material It was observed that the vine growth decreased with increasing level of application of coffee leaves Thus biomass production in this case decreased from 14 61 g plant ^{1} (at 1 per cent level) to 8 76 g plant ^{1} at the highest level (3 per cent) A reverse trend was observed in the case of garuga leaf treatment In this case total biomass produced by the vine increased from 8 88 g plant ^{1} (at 1 per cent level) to 17 59 g plant ^{1} (at 3 per cent level) On the other hand the different levels of application of erythrina and silver oak leaves did not show significant effect on the vine growth When black pepper leaf was used as the organic source the growth of the vine increased to 17 56 g plant ^{1} (at 2 per cent level) and then decreased to 12 39 g plant ^{1} at the highest level of appli cation (3 per cent)

Although there were significant differences among the levels of organic amendments as well as between application of organic sources and control the differences among different leaf materials were not significant (Table 3 and Appendix 1)

1 4 Partioning of dry matter

The data on biomass partitioning expressed as percentage are given in Table 4 Partitioning of shoot dry matter into leaf and stem indicated that there was not much difference in the proportions of leaf and stem among different treatments including control A similar observation was also made with respect to the partitioning of total dry matter In general leaf production accounted for 53 12 per cent of the total biomass The contribution of stem and root to the total biomass production was 32 12 and 14 76 per cent respectively When shoot biomass was considered it was seen that leaf and stem production accounted for 62 32 and 37 68 per cent respectively

2 Nutrient composition of plant parts

2 1 Nitrogen Phosphorus and Potassium

Table 5 gives N P and K concentrations in the leaf and stem of black pepper vines growing under different organic matter

Table 3 Dry matter production in black pepper vine (g $plant^{-1}$) as influenced by the application of various leaf materials

Organic source	Shoot			Root	Total
	Leaf	Stem	Total		
Coffee	6 59	3 98	10 57	1 70	12 27
Erythrina	7 50	3 90	11 40	2 14	13 54
Garuga	6 98	4 45	11 43	1 94	13 37
Silver oak	6 99	3 99	10 98	1 98	12 96
Black pepper	8 12	5 13	13 25	2 24	15 49
SEm±	0 47	0 35	0 79	0 24	1 01
CD (0 05)	NS	NS	NS	NS	NS

NS Not significant

Table 4 Partioning of dry matter production (%) in black pepper vine

Organic source	Shoot dry matter		Total dry matter		
	Leaf	Stem	Root	Leaf	Stem
Coffee					
C_1	61 5	38 5	16 0	51 7	32 3
C_2	62 6	37 4	12 3	54 9	32 8
C_3	63 7	36 3	11 5	56 4	32 1
Erythrina					
E_1	65 7	34 3	17 8	53 8	28 4
E_2	63 0	37 0	15 1	53 5	31 4
E_3	63 7	36 3	11 9	56 2	31 9
Garuga					
G_1	63 2	36 8	13 7	54 5	31 8
G_2	60 4	39 6	13 7	52 2	34 1
G_3	61 9	38 1	14 3	53 1	32 6
Silver oak					
S_1	62 2	37 8	14 8	53 0	32 2
S_2	63 5	36 5	16 0	53 4	30 6
S_3	65 0	35 0	14 5	55 5	30 0
Black pepper					
B_1	63 1	36 9	16 0	53 0	31 0
B_2	57 8	42 2	13 2	50 2	36 6
B_3	63 7	36 3	14 2	54 6	31 2
Control	59 5	40 1	15 9	50 1	34 0

Table 5 N P and K concentrations (%) in the above ground parts of black pepper vine in relation to the application of different leaf materials

Organic source	N		P		K	
	Leaf	Stem	Leaf	Stem	Leaf	Stem
Coffee						
C_1	3 19	0 67	0 146	0 142	3 94	3 67
C_2	2 57	0 86	0 192	0 183	4 25	3 67
C_3	2 48	1 24	0 146	0 171	4 44	3 42
Erythrina						
E_1	2 33	1 14	0 150	0 183	3 73	3 25
E_2	2 57	1 14	0 175	0 200	3 85	3 23
E_3	2 71	1 38	0 167	0 167	4 38	3 79
Garuga						
G_1	2 24	0 91	0 175	0 163	4 13	3 92
G_2	2 36	1 21	0 194	0 207	4 31	4 00
G_3	2 29	1 21	0 201	0 225	4 41	3 81
Silver oak						
S_1	1 90	0 81	0 142	0 158	3 79	3 00
S_2	2 24	1 05	0 158	0 200	4 13	3 56
S_3	2 00	0 95	0 125	0 158	4 06	3 48
Black pepper						
B_1	1 57	0 61	0 138	0 144	4 16	3 44
B_2	1 78	1 71	0 163	0 194	3 97	3 56
B_3	1 71	1 52	0 167	0 208	4 29	3 92
Control	0 71	0 81	0 129	0 104	3 56	2 33
SEm+	0 11	0 11	0 010	0 010	0 17	0 24
CD (0 05)	0 32	0 32	0 028	0 028	0 49	0 69

1 2 and 3 denote rates of application at 1 2 and 3 per cent respectively

treatments The analyses of variance of the data are given in Appendix 2

Significant increases were noticed in the N concentrations of leaf and stem consequent to the application of leaf materials compared to control Higher rates of application of coffee leaves tended to decrease the N concentrations in the leaf while a reverse trend was observed in the case of stem No significant differences were observed among the garuga leaf treatments both in leaf as well as in stem N concentrations Silver oak leaf application at the rate of 2 per cent significantly increased the leaf N content which was more than at 1 per cent level of application But there was no significant difference among silver oak leaf treatments in stem N concentration On the other hand a steady increase in the leaf and stem N concentrations was obtained with increasing level of application of erythrina leaf The vines receiving black pepper leaves did not show much variation in leaf N concentration with increasing rate of application However there was a signifi cant increase in stem N concentration at higher rates of application Among the organic treatments the highest concentration of leaf N (3 19%) was observed in the vines receiving coffee leaves at the rate of 1 per cent and the minimum (1 57%) was found in vines receiving black pepper leaves at 1 per cent level In the case of stem the highest concentration (1 71%) was observed in plants receiving black pepper leaf at the rate of 2 per cent and the minimum (0 61%) was found in vines receiving the same material at 1 per cent level

Soil incorporation of leaf materials significantly increased the phosphorus concentrations of leaf and stem A comparison of different levels of treatments indicated that the increase in leaf P concentration occured up to the second level of application (2 per cent) in all the cases except in the vines receiving erythrina and garuga leaf treatments In these two cases the differences were not significant among the three levels of application Among the different organic treatments the highest concentration of leaf P (0 201%) was recorded by the vines receiving garuga leaves at 3 per cent level while the lowest (0 125%) was recorded by the vines receiving silver oak leaves at 3 per cent level Phosphorus concentration of the stem was also significantly influenced by the levels of organic treatments Whereas application of coffee garuga and black pepper leaves increased the P concentration of the stem there was a decrease in P concentration at the highest level of application of erythrina and silver oak leaves The maximum (0 225%) a minimum (0 142%) concentration of P in the stem of plants under organic treatments were recorded by the vines receiving garuga leaves at the highest level (3 per cent) and by the vines receiving coffee leaves at lowest level (1 per cent) respectively

Compared to control foliar K levels of vines under organic treatments were considerably higher Nevertheless the effect of increasing levels of organic matter application was not marked except in the case of coffee and erythrina leaf treatments Among the treatments plants receiving coffee leaves at the rate of 3 per cent had the highest concentration of foliar K (4 44%) while the minimum (3 73%) was observed in vines receiving erythrina leaf at the rate of 1 per cent Potassium concentration in the vine stem was also significantly higher in vines under organic treatments than in the control vines The effect of varying levels of organic matter had a similar trend to that found in leaf but significant differences were observed

A comparison of the effects of the various leaf materials on N, P and K concentrations of the vine indicated that there were significant differences in their effect on N concentrations of leaf and stem and P concentration of leaf (Table 6 and Appendix 2) The differences in stem P concentration as well as in K contents in leaf and stem were however not significant Application of coffee leaves increased the leaf N content to 2 75 per cent while foliar N level was as low as 1 69 per cent in vines receiving black pepper leaves A reverse trend in the effect of organic material was observed in the case of stem N Foliar P content was highest (0 190%) in plants receiving garuga leaf while it was the least (0 142%) in the vines receiving silver oak leaf

2 2 Calcium magnesium and sulphur

The data pertaining to the Ca Mg and S contents of the above ground parts of black pepper vine are given in Table 7 and Appendix 3

Table 6 Concentrations of N, P and K (%) in aerial parts of pepper vine as influenced by the application of various leaf materials

Organic source	N		P		K	
	Leaf	Stem	Leaf	Stem	Leaf	Stem
Coffee	2 75	0 92	0 161	0 165	4 21	3 58
Erythrina	2 54	1 22	0 164	0 183	3 99	3 42
Garuga	2 30	1 11	0 190	0 198	4 28	3 91
Silver oak	2 05	0 94	0 142	0 172	3 99	3 35
Black pepper	1 69	1 28	0 156	0 182	4 14	3 64
SEm+	0 06	0 06	0 006	0 006	0 10	0 14
CD (0 05)	0 18	0 17	0 017	NS	NS	NS

NS Not significant

Table 7 Ca Mg and S concentrations (%) in the above ground parts of black pepper vine as affected by the application of different leaf materials

Organic source		Calcium		Magnesium		Sulphur	
		Leaf	Stem	Leaf	Stem	Leaf	Stem
Coffee							
	C_1	1 33	1 15	0 192	0 112	0 132	0 071
	C_2	1 36	1 13	0 224	0 104	0 139	0 070
	C_3	1 41	1 15	0 256	0 104	0 152	0 074
Erythrina							
	E_1	1 63	1 24	0 368	0 168	0 137	0 072
	E_2	1 49	1 31	0 216	0 096	0 146	0 063
	E_3	1 53	1 27	0 232	0 144	0 145	0 074
Garuga							
	G_1	1 47	1 33	0 352	0 168	0 133	0 057
	G_2	1 34	1 24	0 262	0 096	0 137	0 067
	G_3	1 36	1 24	0 169	0 144	0 145	0 064
Silver oak							
	S_1	1 51	1 21	0 248	0 112	0 133	0 054
	S_2	1 53	1 35	0 232	0 184	0 150	0 033
	S_3	1 53	1 24	0 112	0 096	0 131	0 042
Black pepper							
	B_1	1 50	1 22	0 168	0 084	0 128	0 055
	B_2	1 64	1 35	0 120	0 078	0 142	0 070
	B_3	1 56	1 34	0 232	0 100	0 129	0 078
Control		1 48	1 21	0 113	0 120	0 119	0 048
SEm+		0 04	0 03	0 040	0 020	0 010	0 003
CD (0 05)		0 12	0 09	0 116	0 057	0 028	0 008

1 2 and 3 denote rates of application at 1 2 and 3 per cent respectively

Calcium levels of leaf and stem and Mg content of stem were not influenced by application of organic materials as was evident from the lack of statistical significance between the control and treatment vines The analyses of variance are given in Appendix 3 On the other hand there was significant differences in leaf Mg concentration between control and organic matter receiving vines (Appendix 3) In the case of S application of leaf materials significantly altered the nutrient levels in leaf and stem (Appendix 3)

Barring three treatments namely erythrina garuga and black pepper leaf sources the level of application had no effect on leaf Ca levels In vines receiving erythrina and garuga leaves foliar Ca levels decreased with increasing level of application whereas in those receiving black pepper leaves foliar Ca level first increased then decreased at the highest level of application Application of leaves of silver oak and black pepper generally increased the Ca content in the stem while there was a declining trend in nutrient concentration in plants receiving garuga leaf at higher levels of application

Foliar Mg levels did not vary with the levels of applicat ion of coffee and black pepper leaves Higher levels of application of erythrina garuga and silver oak leaves generally tended to decrease the foliar Mg level As in the case of foliar Mg levels the rate of application of coffee and black pepper leaves had no effect on the Mg content of stem Application of erythrina and garuga leaves at 2 per cent decreased the stem Mg content while the same level of application of silver oak leaf increased the stem Mg content

Foliar S levels did not vary significantly with the level of application of the leaf materials Stem S content did not vary with the level of application of coffee leaf In other cases the effect was rather inconsistent

Among the sources (Table 8 and Appendix 3) application of black pepper erythrina or silver oak leaf improved the foliar Ca levels of the vine compared to the application of either coffee or garuga leaf The effects of application of erythrina garuga silver oak or black pepper on stem Ca content were at par The application of any one of these materials increased the stem Ca content as compared to the application of coffee leaf In the case of foliar Mg the effect of coffee erythrina and garuga leaves was more or less the same The plants under these treatments showed a higher level of leaf Mg than those under silver oak and black pepper leaf treatments Higher stem Mg was recorded for the vines receiving erythrina garuga or silver oak leaf than those receiving coffee or black pepper leaf Foliar S levels did not vary with the organic source however stem S content was higher in plants under coffee erythrina garuga and black pepper leaf treatments than those under silver oak leaf treatment

Table 8 Ca Mg and S concentrations (%) in the above ground parts of black pepper vine as influenced by the application of various leaf materials

Organic source	Ca		Mg		S	
	Leaf	Stem	Leaf	Stem	Leaf	Stem
Coffee	1 37	1 14	0 224	0 107	0 141	0 073
Erythrina	1 55	1 27	0 272	0 136	0 143	0 070
Garuga	1 39	1 27	0 261	0 136	0 138	0 063
Silver oak	1 52	1 27	0 197	0 131	0 138	0 043
Black pepper	1 57	1 30	0 173	0 087	0 132	0 067
SEm+	0 02	0 02	0 023	0 012	0 006	0 002
CD (0 05)	0 06	0 06	0 066	0 035	NS	0 006

NS - Not significant

2 3 Iron and manganese

The data relating to iron and manganese contents in leaf and stem of black pepper vines are given in Table 9

Foliar Fe content was not influenced by green manuring while a higher Fe content was found in the stem portion of vines receiving organic sources than that of control plants (Appendix 4) In majority of these cases Fe content was more than 100 ppm whereas in control vines it was 90 ppm

There was considerable increase in foliar Mn concentration following the application of leaf materials However the rate of application of the organic sources barring the garuga leaf did not influence Mn concentration Higher levels of application of garuga leaf decreased the foliar Mn content The influence of organic sources on stem Mn content was not significant (Appendix 4)

It was also observed that there were no significant differ ences among the organic sources on Fe and Mn contents of the shoot (Table 10)

3 **Nutrient removal**

The data pertaining to the nutrient removal by black pepper vines as influenced by organic treatments are presented in Tables 11 and 12 The analyses of variance are presented in Appendix 5 It was observed that the vines absorbed significantly higher

Table 9 Fe and Mn concentrations (ppm) in the above ground parts of black pepper vine as influenced by the application of leaf materials

Organic source		Iron		Manganese	
		Leaf	Stem	Leaf	Stem
Coffee					
	C_1	87	123	483	104
	C_2	107	117	437	95
	C_3	117	150	597	115
Erythrina					
	E_1	180	150	548	114
	E_2	183	137	415	100
	E_3	130	163	508	118
Garuga					
	G_1	160	133	642	142
	G_2	120	170	299	63
	G_3	145	90	398	80
Silver oak					
	S_1	147	133	552	132
	S_2	137	177	378	134
	S_3	163	107	373	122
Black peppe					
	B_1	135	130	447	105
	B_2	125	100	381	101
	B_3	153	120	497	140
Control		117	90	290	114
SEm±		27	17	70	18
CD (0 05)		NS	48	202	NS

NS Not significant

1 2 and 3 denote rates of application at 1 2 and 3 per cent respectively

Table 11 Nutrient removal by black pepper vine as influenced by the application of leaf materials

Organic source	N	P	K	Ca	Mg	S	Fe	Mn
	mg plant^{-1}						µg plant^{-1}	
Coffee								
C_1	265 4	17 69	466 4	153 0	19 70	13 38	1236	4032
C_2	227 7	22 31	468 4	149 7	20 74	13 39	1309	3710
C_3	156 6	12 06	314 0	102 2	15 57	9 57	1002	3274
Erythrina								
E_1	191 1	16 40	357 0	148 7	29 45	11 44	1753	3682
E_2	282 6	25 74	495 3	195 9	23 35	16 08	2312	4018
E_3	255 4	19 16	474 2	164 6	23 03	13 63	1617	4148
Garuga								
G_1	130 4	12 85	295 2	106 9	21 19	7 87	1133	3337
G_2	223 3	23 54	470 2	150 4	20 10	13 16	1644	2328
G_3	282 2	31 56	631 5	197 9	23 86	17 23	1836	4260
Silver oak								
S_1	141 3	14 37	332 6	134 1	19 02	9 90	1343	3753
S_2	187 9	17 83	404 8	152 8	22 30	11 29	1601	3071
S_3	210 8	17 37	495 6	184 2	13 43	12 92	1857	3695
Black pepper								
B_1	169 5	19 49	539 3	194 3	18 59	14 03	1844	4448
B_2	266 8	26 84	578 7	231 2	15 52	16 94	1742	3984
B_3	174 5	19 20	439 7	157 1	19 22	11 76	1509	3869
Control	37 9	6 26	157 9	71 3	5 93	4 68	553	1115
SEm±	26 4	2 92	44 9	18 2	2 93	1 79	284	559
CD (0 05)	76 1	8 42	129 3	52 5	8 44	5 16	817	1611

Table 10 Fe and Mn concentrations (ppm) in the above ground parts of black pepper vine as influenced by the application of various leaf materials

Organic source	Fe		Mn	
	Leaf	Stem	Leaf	Stem
Coffee	103	130	506	104
Erythrina	164	150	490	111
Garuga	142	131	446	95
Silver oak	149	139	434	129
Black pepper	138	17	441	115
SEm+	16	10	40	10
CD (0 05)	NS	NS	NS	NS

NS Not significant

Table 12 Uptake of nutrients by the black pepper vine as influenced by the application of different leaf materials

Organic source	N	P	K	Ca	Mg	S	Fe	Mn
	mg plant^{-1}						μg plant^{-1}	
Coffee	216 6	17 35	416 3	137 9	18 67	12 11	1182	3672
Erythrina	243 2	20 43	442 2	169 7	25 27	13 72	1894	3949
Garuga	211 9	22 65	465 6	151 7	21 71	12 75	1538	3308
Silver oak	180 0	16 52	411 0	157 0	18 25	11 37	1601	3506
Black pepper	203 6	21 84	519 2	194 2	17 78	14 24	1698	4101
SEm±	15 2	1 69	25 9	10 5	1 69	1 03	164	323
CD (0 05)	NS	NS	74 6	30 3	4 87	NS	NS	NS

NS Not significant

quantities of N P K Ca Mg S Fe and Mn following the appli cation of organic materials compared to the control vines

The effects of different levels of application of organic sources are presented below

The total quantity of N varied with the level of application of organic sources (Table 11) With increasing level of application of coffee leaves N recovery in the shoot decreased significantly from 265 4 mg (at 1 per cent level) to 156 6 mg plant ^{1} (at 3 per cent level) In the other cases notably in erythrina and garuga leaf treatments nitrogen uptake was enhanced at higher levels of application Application of black pepper leaves increased the N uptake up to the second level of application (2 per cent) beyond which there was a decrease Nitrogen uptake was maximum (282 6 mg plant ^{1}) in vines receiving erythrina leaves at 2 per cent level and was minimum (130 4 mg plant^{-1}) for vines receiving garuga leaves at 1 per cent level

The rate of application of leaf materials had a variable effect on phosphorus removal by the vine (Table 11) Phosphorus removal was increased at higher rates of application of coffee erythrina and garuga leaves Nevertheless in the case of coffee a significant decrease in P removal was noticed when the rate of application was 3 per cent The differences in P uptake among the levels of application of silver oak and black pepper leaf treat- ments were not significant Highest uptake of P (31 56 mg plant^{-1})

was observed in vines receiving garuga leaves at 3 per cent level while the lowest (12 06 mg plant ^{1}) was recorded in vines receiving coffee leaves at 3 per cent level

Potassium uptake was found to increase with increasing level of application of erythrina garuga and silver oak leaves In the case of coffee and black pepper leaf treatments the highest rate of application (3 per cent) had a negative effect Potassium uptake was maximum (631 5 mg plant ^{1}) and minimum (295 2 mg plant ^{1}) in the vines receiving garuga leaf at 3 and 1 per cent levels respectively (Table 11)

Calcium uptake was not affected by the different levels of application except in garuga and black pepper leaf treatments (Table 11) In the case of garuga leaf treatment, there was a steady increase in the uptake of Ca with increasing level of appli cation Application of black pepper leaves increased the Ca uptake up to the second level of application (2 per cent) beyond which there was a decrease Maximum uptake of Ca (231 2 mg plant ^{1}) was observed for the vines receiving black pepper leaves at 2 per cent level while the least (102 2 mg plant ^{1}) was recorded for the vines receiving coffee leaves at 3 per cent level

Removal of Mg by the black pepper vine also did not show significant differences among the levels of different treatments However a steep decline occured at 3 per cent level of application of silver oak leaves (Table 11) Uptake of Mg was the highest (29 45 mg plant ^{1}) for vines receiving erythrina leaves at 1 per cent level and was minimum (13 43 mg plant ^{1}) for vines receiving silver oak leaves at 3 per cent level

In the case of S uptake two treatments namely garuga and black pepper leaf application showed significant differences (Table 11) While the application of garuga leaves tended to increase the S uptake the application of black pepper leaves at 3 per cent level decreased it Sulphur uptake was maximum (17 23 mg plant ^{1}) and minimum (7 87 mg plant ^{1}) for the vines receiving garuga leaves at 3 and 1 per cent levels respectively

The differences in Fe and Mn uptake by the pepper vine at different levels of application of organic sources were not signi ficant (Table 11) But in one case viz garuga leaf treatment, the uptake of Mn increased significantly from 2328 µg plant ^{1} at 2 per cent level of application to 4260 µg plant ^{1} at 3 per cent level of application A maximum uptake of Fe (2312 µg plant^{-1}) was observed for vines receiving erythrina leaves at 2 per cent level and the least (1002 µg plant ^{1}) was observed for vines receiving coffee leaves at 3 per cent level Manganese uptake was highest (4448 µg plant ^{1}) in vines receiving black pepper leaves at 1 per cent level whereas it was least (2328 µg plant ^{1}) when application of garuga leaf is done at 2 per cent level

A general comparison of different organic sources in relation to nutrient removal by black pepper vine is given in Table 12 The analyses of variance are given in Appendix-5 It was observed that the different sources had more or less similar effect on the uptake of N P S Fe and Mn Application of black pepper leaf signficatly increased uptake of K The lowest values for K uptake were observed for vines receiving coffee and silver oak leaves Calcium uptake was also enhanced by the application of black pepper leaves while that of Mg was not influenced

An evaluation of the nutrient removal by the experimental vines indicated the following order K > N > Ca > Mg > P > S > Mn > Fe(Table 13) Of these the major portion was contributed by leaves (Fig 1)

4 Inter relationships between leaf nutrients and dry matter production

The correlations between dry matter production and leaf nutrient concentrations are given in Table 14 Leaf nutrient concentrations did not show significant relationships with biomasss production The existence of significant relationships among the concentrations of some of the leaf nutrients are however evident Positive correlations were obtained between the contents of N and S (r   0 595*), P and K (r   0 549*) K and S (r - 0 498*), Ca and Fe (r   0 556*) and Mg and Mn (r   0 678**) The correlation

Table 13 Nutrient removal by six month old black pepper vine grown in pots

Nutrient	Plant part		Total
	Leaf	Stem	
-mg-			
N	153 78 (2 17)	46 41 (1 08)	200 19
P	11 34 (0 16)	7 58 (0 18)	18 92
K	284 96 (4 09)	147 57 (3 50)	432 53
Ca	103 20 (1 48)	52 69 (1 25)	155 89
Mg	14 64 (0 22)	4 80 (0 12)	19 44
S	9 67 (0 14)	2 66 (0 06)	12 33
- µg-			
Fe	974 00 (138 00)	543 00 (131 00)	1517 00
Mn	3096 00 (453 00)	450 00 (111 00)	3546 00

Values are means of fourty eight plants

Parentheses denote nutrient concentrations expressed as percentage dry matter for major nutrients and as ppm for micronutrients

Fig.1. Partitioning of nutrient removal in six-month-old black pepper vine

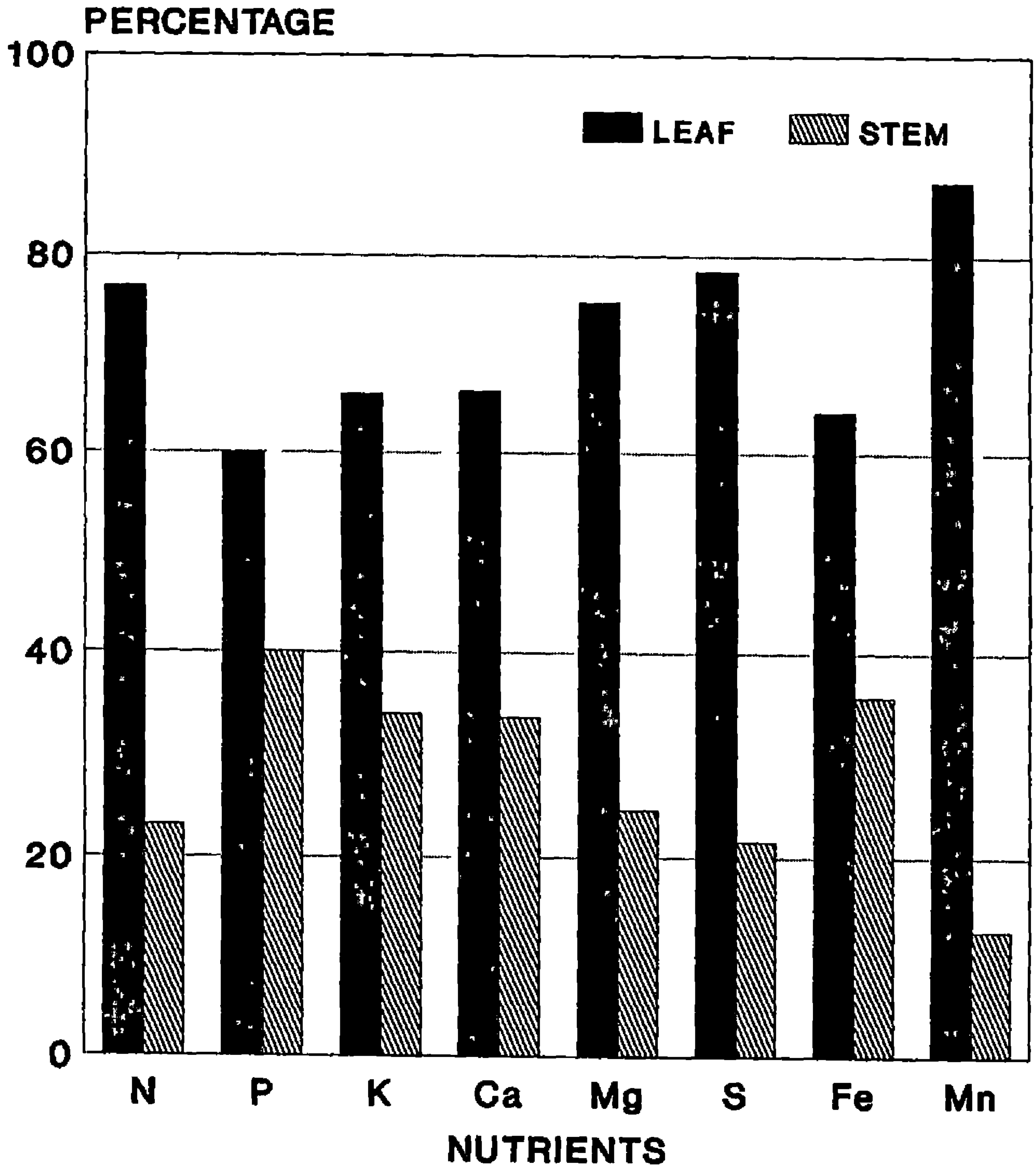


Table 14 Correlations (r values) among leaf nutrient concentrations and dry matter production in black pepper vine

		Dry matter			Leaf nutrients						
		Total	Shoot	Root	N	P	K	Ca	Mg	S	Fe
Leaf	N	0 316	0 319	0 257							
	P	0 206	0 227	0 068	0 450						
	K	0 225	0 276	0 066	0 390	0 549*					
	Ca	0 030	0 017	-0 096	0 399	-0 521*	0 375				
	Mg	0 344	-0 366	0 185	0 407	0 380	0 098	0 016			
	S	0 271	0 300	0 088	0 595*	0 386	0 498*	0 049	0 233		
	Fe	0 117	0 090	0 244	0 122	0 035	0 208	0 556*	0 330	0 059	
	Mn	-0 291	0 287	0 275	0 355	-0 009	0 155	0 111	0 678**	0 168	0 207

** Significant at 1 per cent level
* Significant at 5 per cent level

between P and Ca was negative (r   0 521*) Regression equations were worked out for the leaf nutrients showing significant correlations and are presented in Table 15 The highly significant relation ships obtained between foliar N and S and Mg and Mn are dipicted in Figures 2 and 3

5 Changes in chemical properties of soil

Physlco chemlcal properties of the soil used In the experi ment and chemical characteristics of the soil after the experiment (pot culture) are given in Tables 16 and 17 respectively

The soil is acidic in reaction with an organic carbon content of 1 05 per cent and is low in major nutrient contents

Significant differences were observed in chemical characteristics of the soil at the end of the experiment (Table 17 and Appendix-6)

The pH of the control soil decreased to 5 5 (Table 17) from the initial value of 5 7 (Table 16) Application of different leaf materials had a variable effect on soil pH compared to the control Soil pH decreased significantly following the application of coffee leaves at 3 per cent level Barring this no regular trend was observed in the changes in soil pH due to the application of other leaf materials although slightly higher pH was recorded for soil receiving black pepper leaves at 1 per cent level of application

Table 15 Regression equations for the significant relationships between leaf nutrients

X	Y	Regression equation	R^2	r
S	N	Y 3 985 + 44 1620 X	0 617	0 595*
K	P	Y 0 299 + 0 0466 X	0 283	0 549*
Ca	P	Y 0 396 0 1563 X	0 359	0 521*
S	K	Y 2 070 + 14 6880 X	0 250	0 498*
Fe	Ca	Y 1 204 + 0 0020 X	0 296	0 556
Mn	Mg	Y 0 116 + 0 0007 X	0 708	0 678**

** Significant at 1 per cent level
* Significant at 5 per cent level

Fig.2. Relationship between foliar N and S concentrations

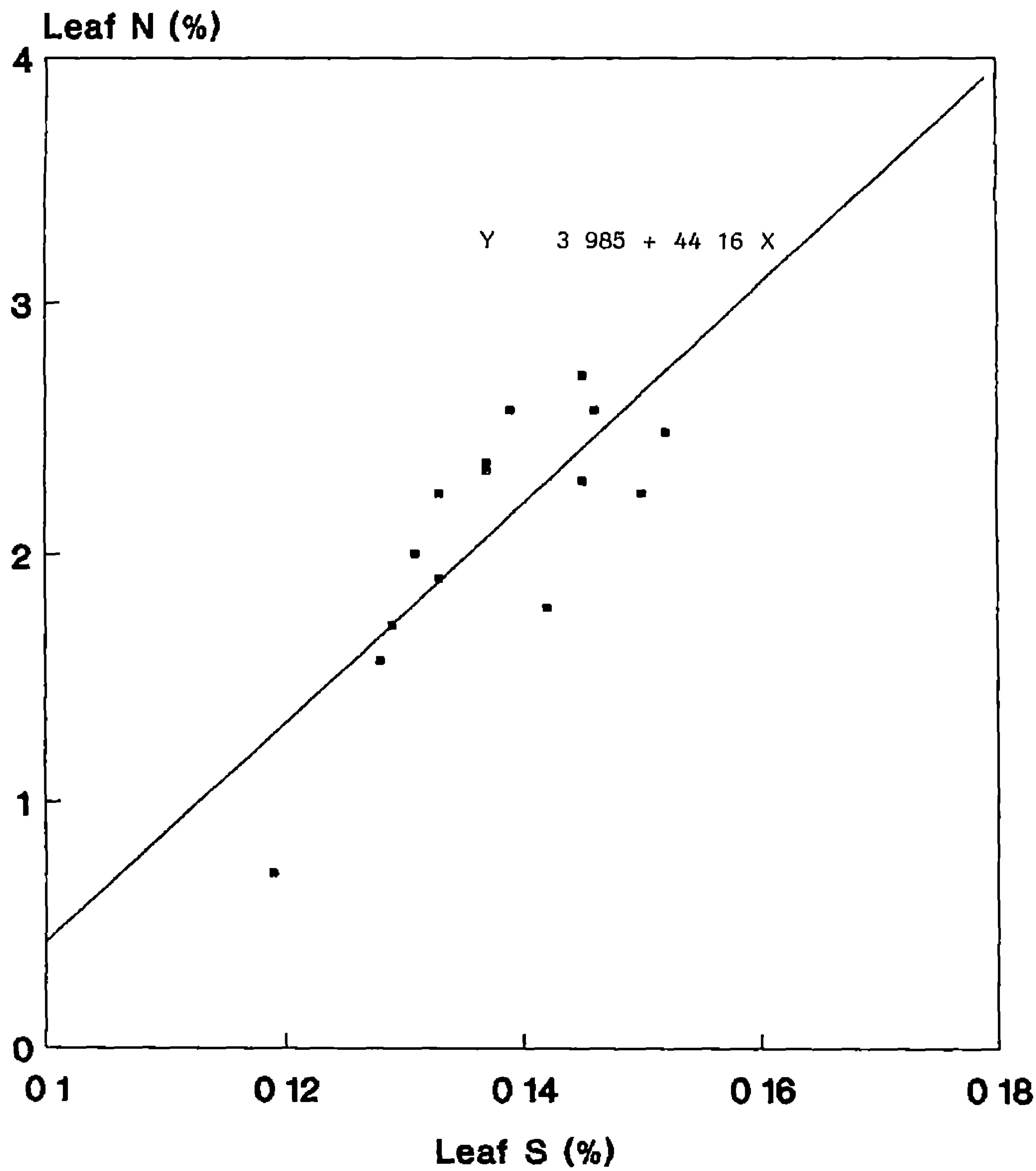


Fig.3. Relationship between foliar Mg and Mn concentrations

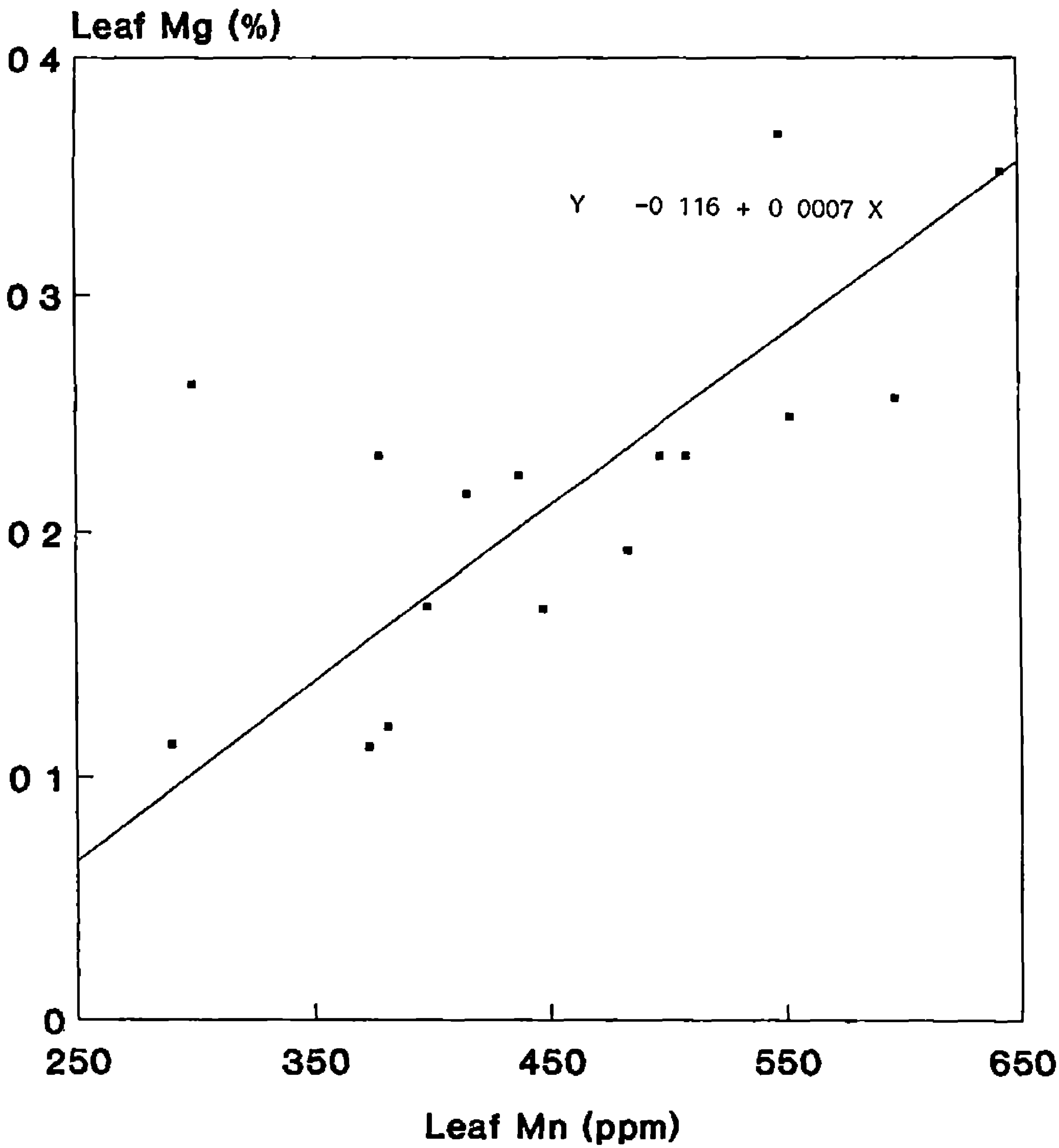


Table 16 Physico chemical properties of the soil used in the study

Property	Value
A <u>Physical properties</u>	
1 Particle size analysis	
Coarse sand (%)	8 8
Fine sand (%)	50 2
Silt (%)	34 8
Clay (%)	6 2
2 Maximum water holding capacity (%)	37 7
B <u>Chemical properties</u>	
1 pH	5 7
2 Organic carbon (%)	1 05
3 Available P (ppm)	3 58
4 Exchangeable K (cmol(+) kg ^{1})	0 27
5 Exchangeable Ca (cmol(+) kg ^{1})	1 50
6 Exchangeable Mg (cmol(+) kg ^{1})	0 31
7 Available S (ppm)	44 0
8 Available Fe (ppm)	8 8
9 Available Mn (ppm)	69 7

Table 17 Chemical characteristics of the soil at the end of pot culture experiment as influenced by the application of various organic sources

Leaf material		pH	Organic carbon(%)	Av P (ppm)	Exch K	Exch Ca	Exch Mg	Av S	Av Fe	Av Mn
					-- cmol(+) kg $^{-1}$		--	-- ppm		-
Coffee	C1	5 58	1 22	7 05	0 393	2 67	0 460	74 7	13 3	69 8
	C2	5 48	1 45	12 57	0 577	2 75	0 583	62 6	12 5	72 8
	C3	5 22	1 48	10 76	0 963	3 08	0 417	73 8	11 7	73 3
Erythrina	E1	5 47	1 16	6 76	0 323	2 33	0 417	57 6	9 3	59 9
	E2	5 35	1 29	11 34	0 440	2 33	0 667	73 7	9 6	63 9
	E3	5 47	1 42	18 86	0 707	2 75	0 583	67 6	11 2	75 9
Garuga	G1	5 55	1 11	11 24	0 287	2 17	0 627	56 5	12 8	62 7
	G2	5 35	1 28	9 29	0 500	2 38	0 627	81 8	11 6	72 1
	G3	5 58	1 47	11 00	0 520	2 63	0 877	94 0	10 4	73 3
Silver oak	S1	5 45	1 22	7 24	0 287	1 92	0 583	76 8	12 3	64 4
	S2	5 52	1 36	8 57	0 343	2 17	0 750	62 6	12 0	75 7
	S3	5 62	1 46	10 10	0 483	2 83	0 667	66 6	14 4	81 8
Black pepper	B1	5 68	1 25	7 43	0 347	2 25	0 627	72 7	11 2	65 6
	B2	5 25	1 55	6 86	0 633	2 88	1 000	78 8	11 2	75 0
	B3	5 57	1 49	10 29	0 833	3 08	1 167	76 7	12 8	80 9
Control		5 50	1 01	5 62	0 200	1 92	0 417	48 5	12 3	61 3
SEm+		0 06	0 10	0 79	0 030	0 13	0 120	4 9	0 6	3 4
CD (0 05)		0 17	0 29	2 28	0 086	0 38	0 346	14 1	1 8	9 8

1 2 and 3 denote rates of application at 1 2 and 3 per cent respectively

Compared to control organic carbon content of the soil receiving different leaf materials were much higher The highest organic carbon content (1 55 per cent) was obtained following the application of black pepper leaves at 2 per cent level

Available P in the soil also increased substantially consequent to the application of organic sources The highest concentration of available P (18 86 ppm) was observed for the erythrina leaf treatment at 3 per cent level whereas it was only 5 62 ppm in the control soil In general with increasing level of application of leaf material available P content of the soil also increased

Substantial increases in exchangeable cations namely K, Ca and Mg were noticed as a result of the application of the organic sources Exchangeable K content increased from 0 200 cmol(+) kg^{1} in the control soil to 0 963 cmol(+) kg^{-1} in the soil receiving coffee leaf at 3 per cent level With increasing level of application of leaf materials exchangeable K content of the soil also increased Exchangeable Ca content increased from 1 92 cmol(+) kg^{-1} (control) to 3 08 cmol(+) kg^{1} at the highest level of application of coffee and black pepper leaves In this case also there was an increasing trend with increasing levels of application of leaf materials Exchangeable Mg also showed a similar trend The exchangeable Mg content of the control soil was 0 417 cmol(+) kg^{1} which rose to 1 167 cmol(+) kg^{1} following the application of black pepper leaf at 3 per cent level Among the organic sources black pepper leaf was found to enhance the exchangeable Mg content more than the other treatments

Significant increases in available S concentration of the soil was also observed following the application of leaf materials Soil available S increased from 48 5 ppm in the control to 94 ppm in the soil receiving garuga leaf at 3 per cent level Although application of leaf materials increased the available S content of the soil not much differences were observed among the levels of application the only exception being the garuga leaf treatment in which higher rates of application increased the available S substantially

Available Fe content of the soil was not influenced by the application of coffee garuga silver oak or black pepper leaves Nevertheless, following the application of erythrina leaf, there was a tendency for the available Fe content of the soil to decrease

In the case of Mn availability there was an increase following the application of organic sources The effect was more pronounced in soils receiving erythrina garuga silver oak and black pepper leaves, while the increase was marginal due to coffee leaf application

6 Nutrient composition of the different leaf materials

The nutrient composition of the different leaf materials used in the study are presented in Table 18 A comparison of the nutrient

Table 18 Nutrient compositions of the different leaf materials used in the study

Nutrient	Coffea arabica	Erythrina indica	Garuga pinnata	Grevilea robusta	Piper nigrum
N	3 43	4 07	2 96	1 96	2 64
P	0 150	0 275	0 213	0 075	0 125
K	2 63	2 13	1 84	1 25	2 41
Ca	1 04	1 88	1 22	1 30	1 68
Mg	0 168	0 156	0 192	0 060	0 708
S	0 125	0 170	0 125	0 072	0 117
Fe	65	95	230	250	310
Mn	25	16	12	8	1064

Note Fe and Mn are in ppm

The concentrations of other nutrients are expressed in percentage concentrations in these materials indicated that erythrina leaf contained very high concentration of N (4 07%) whereas Grevilea robusta (Silver oak) leaves had the least (1 96%) A similar trend was observed in the case of P also The K content of coffee leaves was the highest (2 63%) Erythrina leaf also recorded highest content of Ca and S Black pepper leaves recorded the highest values for Fe and Mn The lowest concentration of all the nutrients excepting Ca and Fe were found for Grevilea leaves The lowest value for Ca was recorded by coffee leaves whereas that of Mn was recorded by Grevilea leaf The most glaring observation is the wide difference between the Mn content of black pepper leaves and the leaves of other trees While the former had a concentration of about 1000 ppm the others contained less than 25 ppm

7 1 Decomposition of leaf materials in soil in laboratory conditions

To study the decomposition of leaf materials in soil under laboratory condition soil was incubated separately for varying lengths of time after incorporating different leaf materials at different levels Organic carbon was estimated at different intervals to provide an index of decomposition

The data were subjected to regression analysis based on the exponential model suggested by Olson (1963) of the form X/X° e^{-kt} (where X is the weight remaining at time t X° is the original weight, e is the base of logarithm k is the decay rate constant and t is time) for describing decomposition of litters was evaluated for goodness of fit to describe the disappearance of organic carbon with time Rearranging this equation we have

$$X \quad X^{o} e^{kt}$$

where X is the organic carbon remaining at time t X^{o} is the organic carbon at time zero e is the base of the logarithm k is the decay rate coefficient and t is time The decay rate constants obtained were also tested for their statistical significance using analysis of variance (Appendix 7) The results of the regression analyses of the data are presented in Table 19

The half life values (0 693/k) indicated that 3 per cent level of garuga leaf application had lowest half-life value of 91 days (R^2 0 915) while the highest half life of 193 days was recorded for 2 per cent level of incorporation of black pepper leaves (R^2 0 684) It was observed that decay rate coefficient (k) was more at all the three levels of incorporation of garuga leaf The half life values of the different leaf materials added to soil at different levels varied to some extent as evidenced from the date given in Table 19

The loss in organic carbon content of the soil with respect to time (days) of different organic sources at different levels are presented in Figures 4 to 8 The decay rate coefficients for all

Table 19 Rates of decomposition of different organic materials in laboratory incubation experiment

Leaf source		Intercept	k (day ^{1})	$t_{\frac{1}{2}}$ (d)	R^2
Coffee					
	C_1	0 4607	0 0044**	158	0 901
	C_2	0 5653	0 0032NS		0 594
	C_3	0 8231	0 0043**	161	0 943
Erythrina					
	E_1	0 4373	0 0045**	154	0 939
	E_2	0 7347	0 0059**	118	0 843
	E_3	0 8290	0 0051*	136	0 710
Garuga					
	G_1	0 5290	0 0056*	124	0 757
	G_2	0 6976	0 0049*	141	0 837
	G_3	0 9685	0 0076**	91	0 915
Silver oak					
	S_1	0 4249	0 0047**	147	0 862
	S_2	0 6729	0 0040**	137	0 893
	S_3	0 8936	0 0044**	158	0 920
Black pepper					
	B_1	0 5164	0 0049**	141	0 903
	B_2	0 6811	0 0036*	193	0 684
	B_3	0 9566	0 0060**	116	0 946

NS - Not significant

* Significant at 1 per cent level
** Significant at 5 per cent level

1 2 and 3 denote rates of application at 1 2 and 3 per cent respectively

Fig.4. Organic carbon content of soil following incorporation of coffee leaves as a function of time

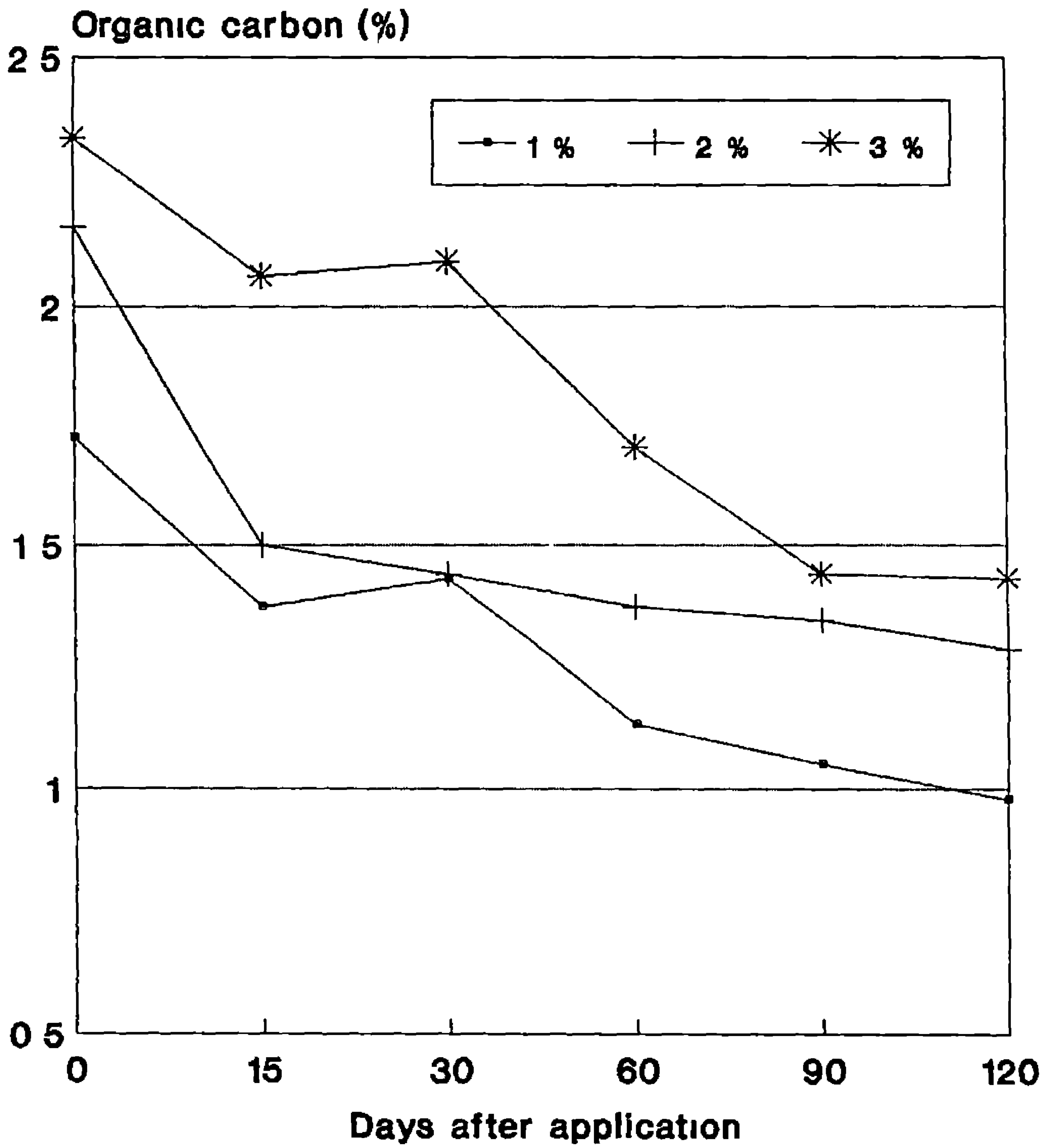


Fig.5. Organic carbon content of soil following incorporation of erythrina leaves as a function of time

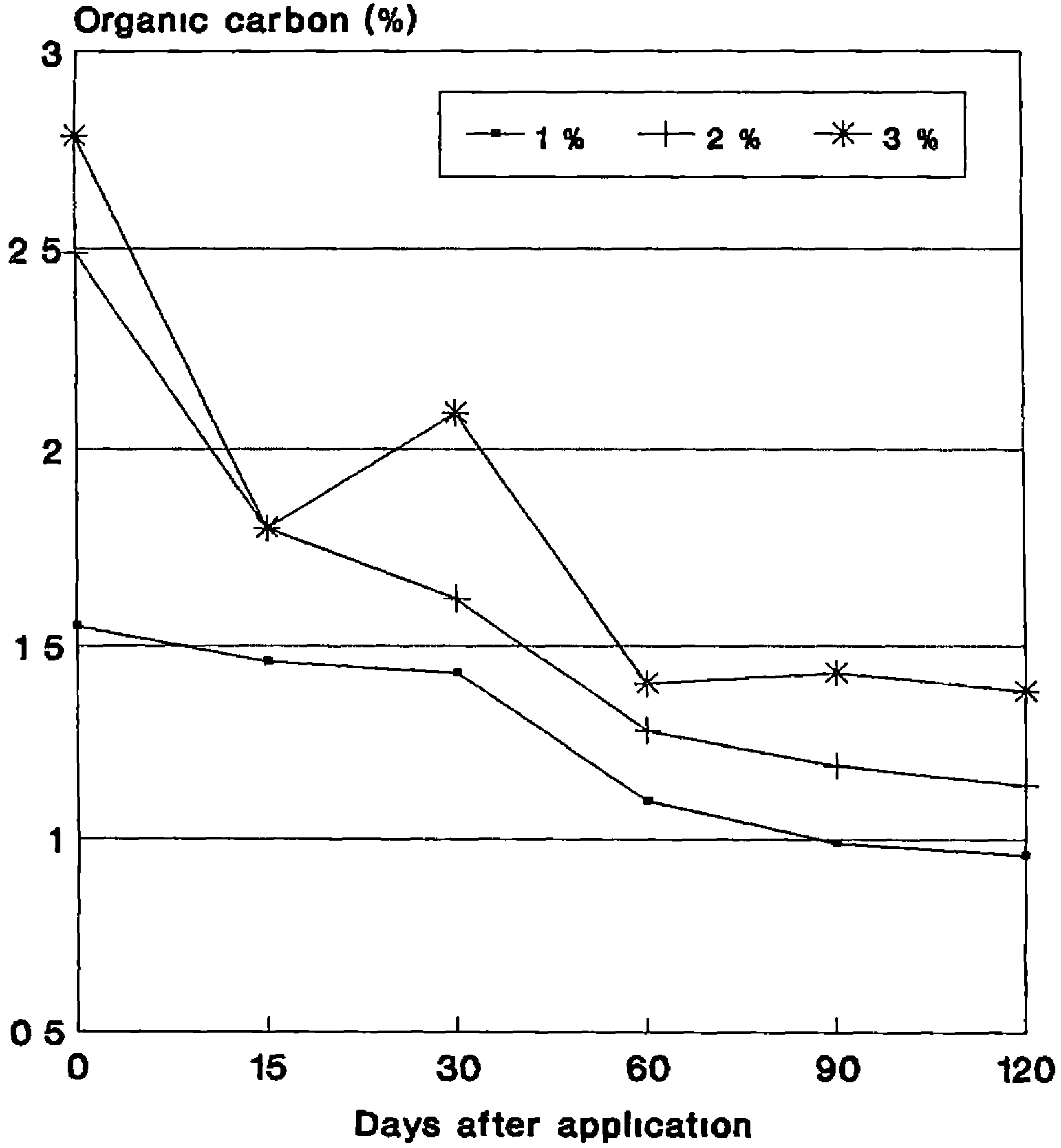


Fig.6. Organic carbon content of soil following incorporation of garuga leaves as a function of time

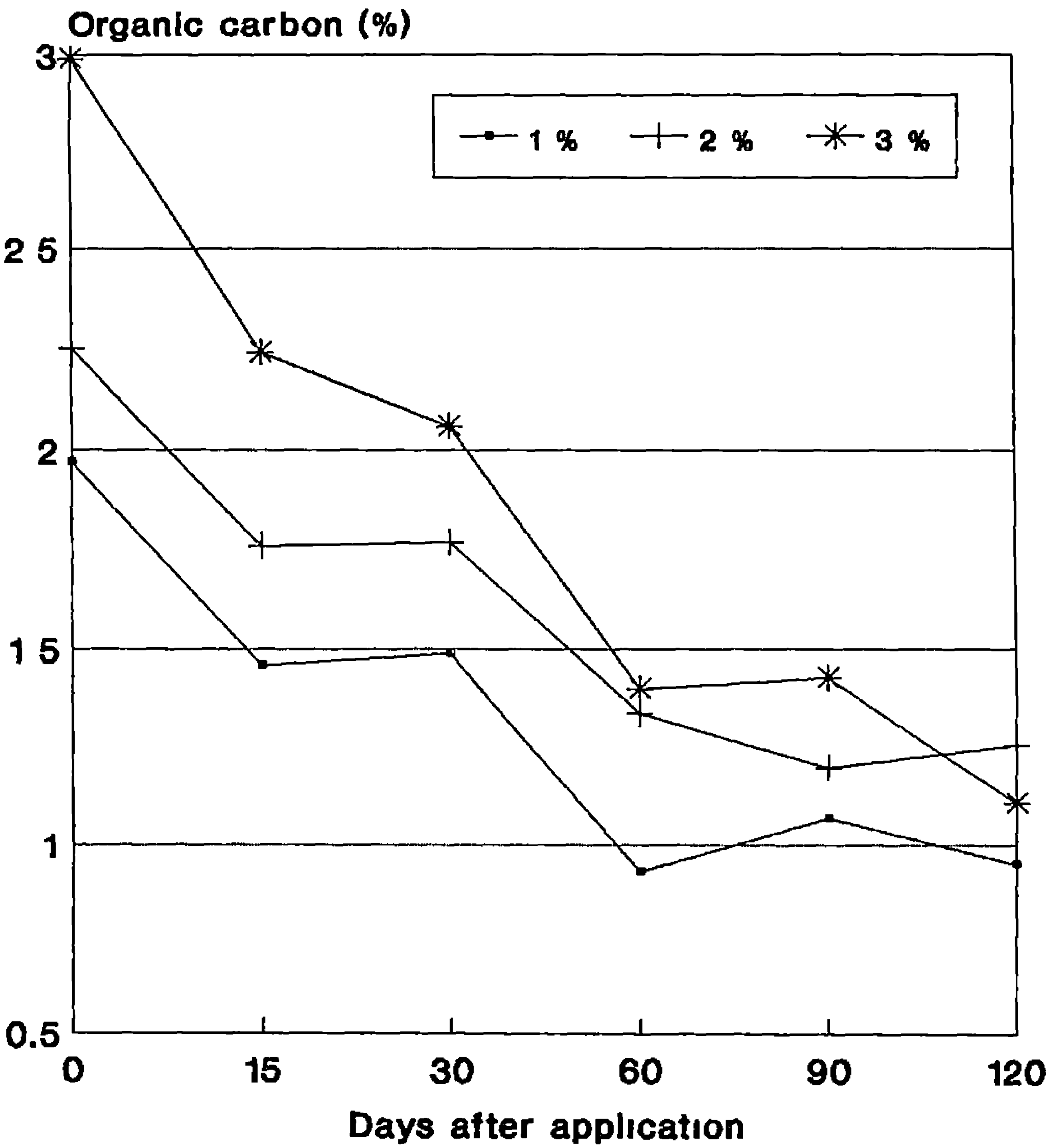


Fig.7. Organic carbon content of soil following incorporation of silver oak leaves as a function of time

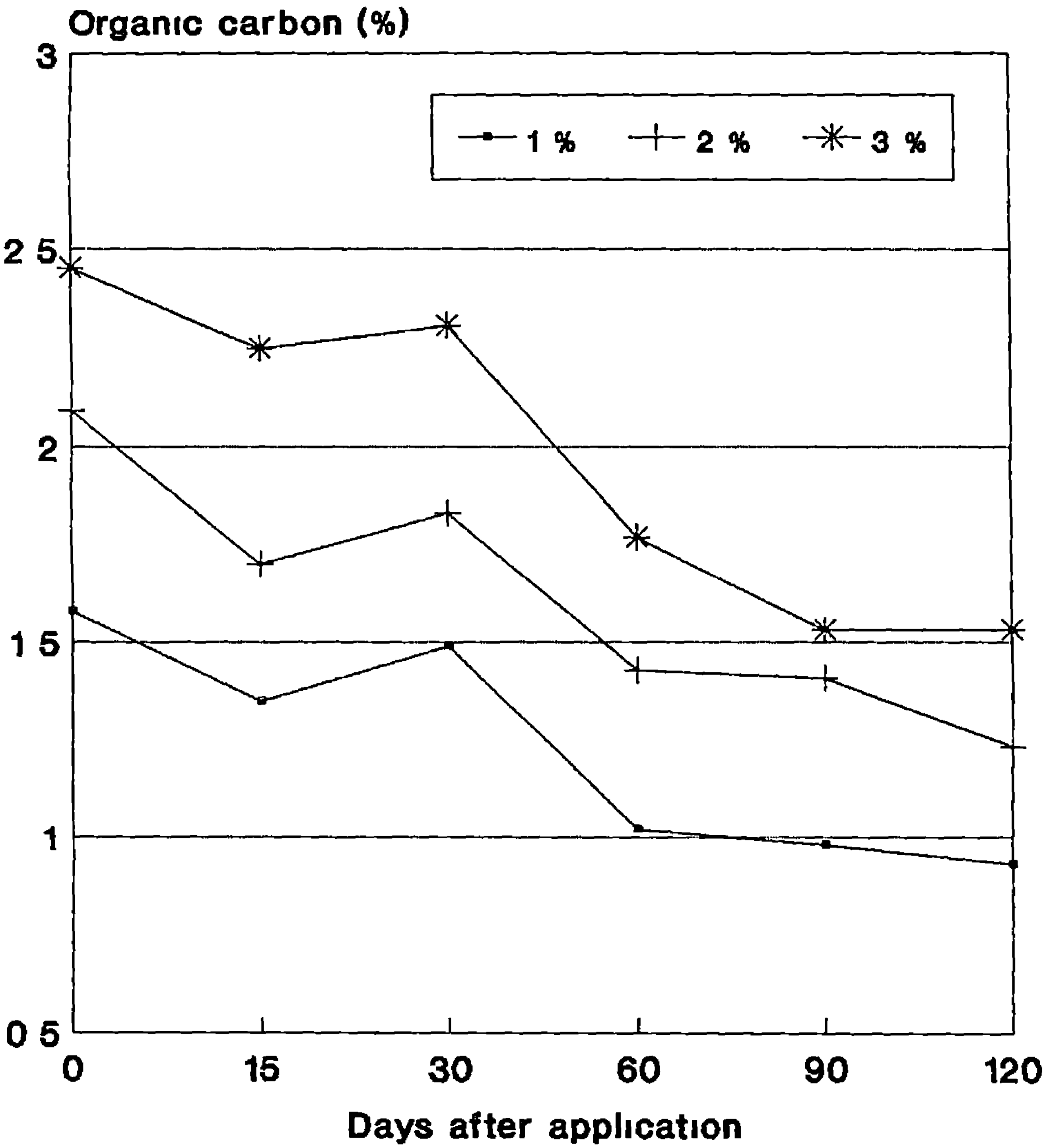
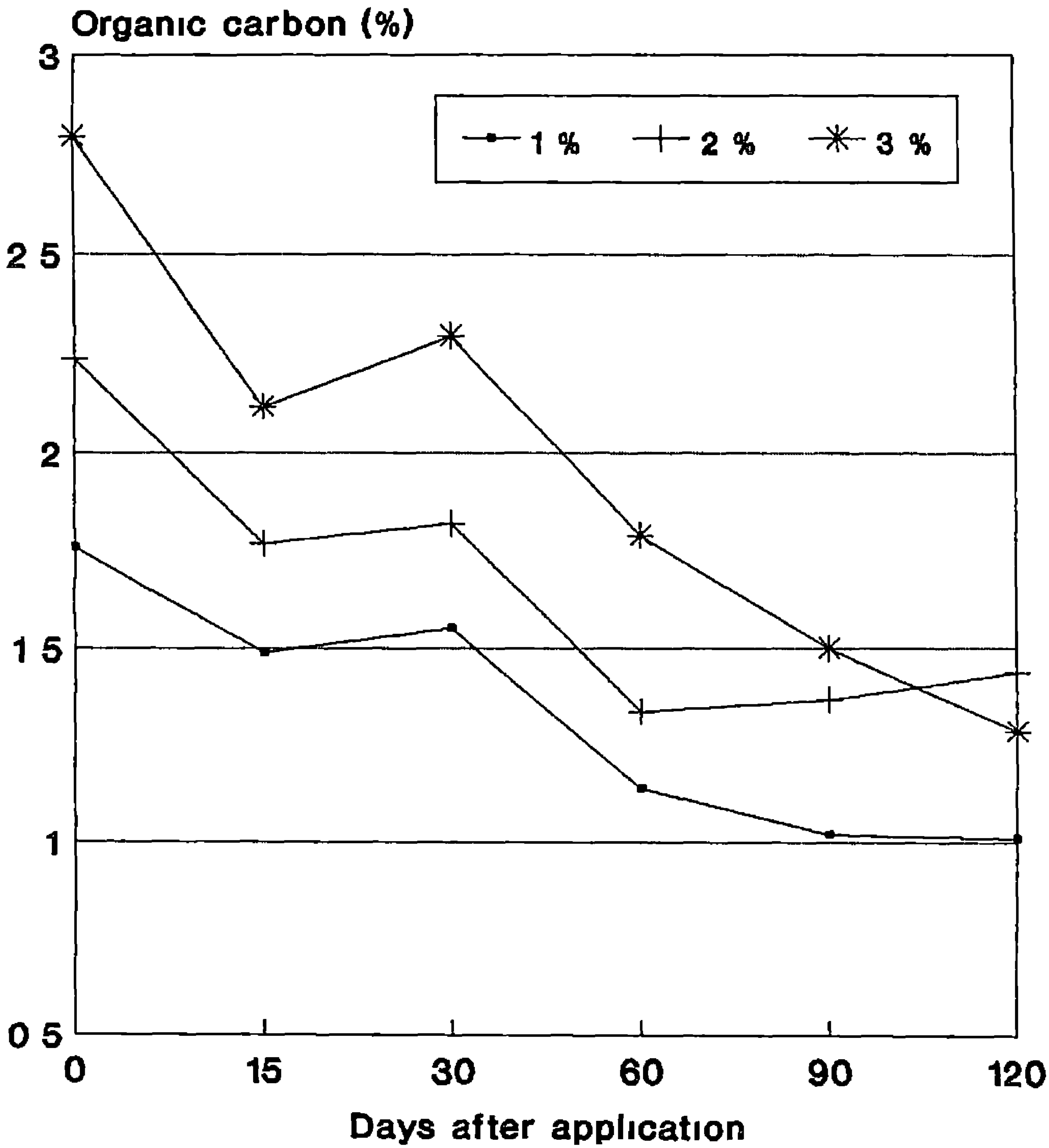


Fig.8. Organic carbon content of soil following incorporation of black pepper leaves as a function of time



the organic matter sources at all levels of incorporation were significant (Table 19) except when coffee leaves at 2 per cent level was the organic source The organic carbon loss under garuga and black pepper leaf treatments followed a similar pattern in the sense that in both cases 3 per cent level of application resulted in higher decomposition rate coefficients (k) of 0 0076 and 0 0060, with R^2 values of 0 915 and 0 946 respectively In the case of coffee erythrina and silver oak leaf treatments no particular trend was observed in decay rate cofficients

On an average the rate of organic carbon loss was slowest in soil with coffee or silver oak leaf as the organic source and fastest when the garuga leaf was the source

7 2 Nutrient availability in incubated soils

The chemical characteristics of the soil namely pH organic carbon available major and micronutrients differed significantly at day 60 of incubation following incorporation with different leaf materials (Table 20 and Appendix 8)

Soil pH ranged from 4 60 (at 3 per cent level of application of erythrina leaves) to 5 73 (at 1 per cent level of coffee and 3 per cent level of application of silver oak leaves) A significant decrease in pH from 5 18 (at 1 per cent level) to 4 60 (at 3 per cent level) was recorded following the erythrina leaf treatment Barring this no particular trend was observed in soil pH due to

Table 20 Chemical characteristics of the soil as influenced by the application of various leaf materials after 60 days of incubation

Organic source		pH	Organic carbon(%)	Av P (ppm)	Exch K	Exch Ca	Exch Mg	Av S	Av Fe	Av Mn
					---	cmol(+) kg^{-1}	---	---	ppm	---
Coffee	C1	5 73	1 13	5 00	0 680	1 88	0 88	66 7	34 0	124 3
	C2	5 40	1 37	4 72	1 270	2 50	0 63	57 6	48 0	164 6
	C3	5 55	1 71	4 43	1 790	2 88	0 88	54 5	34 4	118 7
Erythrina	E1	5 18	1 10	5 58	0 650	2 38	0 75	51 5	20 0	106 9
	E2	5 05	1 28	7 86	1 060	2 88	0 88	65 2	16 0	162 5
	E3	4 60	1 40	9 87	1 480	3 00	1 19	75 8	10 4	129 9
Garuga	G1	5 23	0 93	4 29	0 595	2 25	0 38	56 1	26 0	86 1
	G2	5 10	1 34	5 43	0 935	2 63	0 88	63 6	14 0	113 9
	G3	5 45	1 40	7 00	1 165	2 75	1 00	90 9	8 8	89 3
Silver oak	S1	5 60	1 02	2 86	0 425	1 88	0 32	39 4	19 6	76 9
	S2	5 58	1 43	2 57	0 670	2 19	0 82	42 4	8 4	57 1
	S3	5 73	1 77	3 64	0 880	2 50	0 88	39 4	12 0	96 0
Black pepper	B1	5 60	1 14	4 07	0 660	2 50	0 63	44 0	25 2	146 0
	B2	5 58	1 34	4 29	1 180	3 07	0 76	45 5	11 6	96 8
	B3	5 70	1 79	4 00	1 325	3 19	0 88	54 5	11 2	96 2
SEm+		0 09	0 06	0 20	0 030	0 08	0 11	1 9	4 8	30 5
CD (0 05)		0 27	0 18	0 60	0 090	0 24	0 33	5 7	14 4	NS

NS Not significant

1 2 and 3 denote rates of application at 1 2 and 3 per cent respectively

different levels of application of the leaf materials However except ing erythrina for all other organic sources the lowest pH was recorded at 2 per cent level of application

Organic carbon content of the soil ranged from 0 93% (at 1 per cent level of garuga) to 1 79% (at 3 per cent level of black pepper) In all the cases increasing levels of application significantly increased the organic carbon content of the soil

Available P concentration in soil ranged from 2 57 ppm (at 2 per cent level of silver oak) to 9 87 ppm (at 3 per cent level of erhtyrina) Following the application of erythrina garuga and silver oak leaves an increase in available P content in soil was recorded at higher levels There were no significant differences in available P content of soil due to application of coffee or black pepper leaf at different levels However lower values of available P were observed for the highest level of application of coffee and black pepper leaves Available P content of the soil was more or less same as that of initial soil value when the organic source was silver oak

An attempt was also made to quantify the differences in labile P pool based on the radiotracer technique using P-32 Since the concentration of P in the equilibrium solution was too small to be detected this parameter could not be evaluated

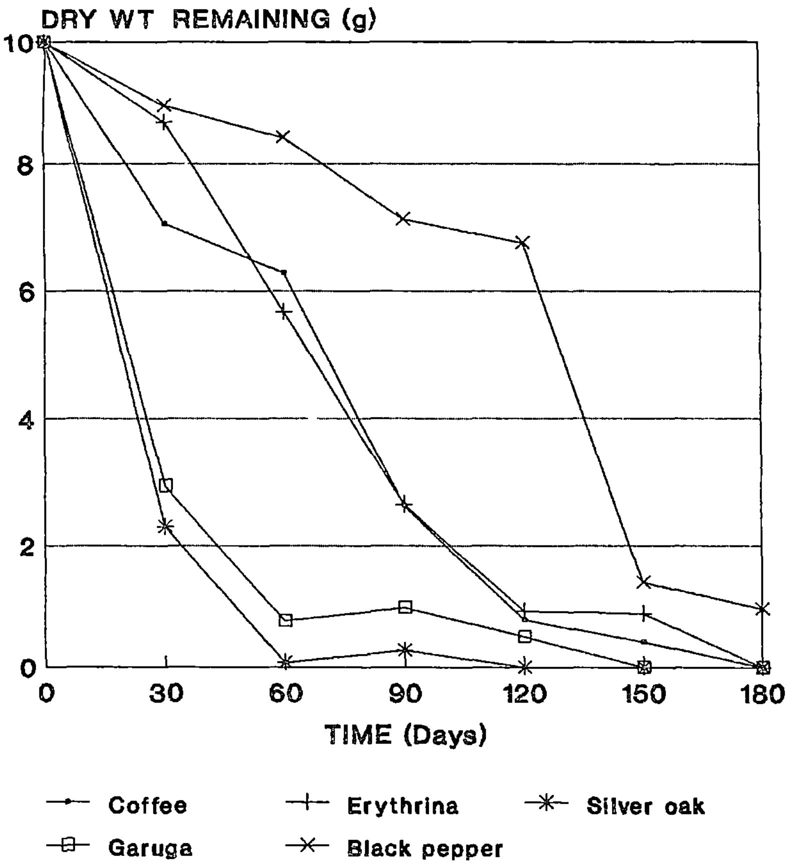
Exchangeable K Ca and Mg showed an increasing trend in their availability following the application of leaf materials at higher levels Exchangeable K in soil was maximum (1 79 cmol(+) kg ^{1}) for 3 per cent level of application of coffee leaf and was minimum (0 425 cmol(+) kg ^{1}) when silver oak leaf was applied at 1 per cent level Lower exchangeable K values were recorded for the soil incubated with silver oak leaf compared to other sources Exchangeable Ca was maximum (3 19 cmol(+) kg^{-1}) when black pepper leaf was applied at 3 per cent level and was minimum (1 88 cmol(+) kg ^{1}) for coffee and silver oak leaf applications at 1 per cent level Relatively higher exchangeable Ca values were recorded for the soil receiving black pepper leaf and lower values were observed for silver oak leaf treatments Exchangeable Mg was the highest (1 19 cmol(+) kg ^{1}) in soils receiving erythrina leaf at 3 per cent level and the lower (0 32 cmol(+) kg ^{1}) in soils receiving silver oak leaf at 1 per cent level An increase in the availability of Mg was noticed with increasing level of application in all the cases except in soils where coffee or black pepper leaf was used as the organic source Relatively higher exchangeable Mg values were obtained for soils receiving erythrina leaf than other organic sources

Significant increase in available S was noticed with increasing levels of application of erythrina and garuga leaf Available S content of soil decreased singificantly with increasing level of application of coffee leaf from 66.7 ppm (at 1 per cent level) to 54.5 ppm (at 3 per cent level). No significant differences in available S were observed due to varying levels of application of silver oak and black pepper leaves. The available S content of soil receiving silver oak leaf was more or less same as that of initial soil value (44 ppm). Available S was maximum (90 ppm) in soils receiving garuga leaf at 3 per cent level and was the least (39.4 ppm) in soils receiving silver oak leaves at 1 and 3 per cent levels.

Available Fe concentration in soil differed signficantly with respect to different treatments. Among the different levels of appli-cation, only garuga leaf showed a significant decrease in available Fe from 26 ppm (at 1 per cent level) to 8.8 ppm (at 3 per cent level). Available iron content was highest (48 ppm) in soil incubated with coffee leaves at 2 per cent level whereas it was least (8.4 ppm) in soil incubated with silver oak leaves at 2 per cent level.

No significant differences were seen in the available Mn content of the soils incubated with different leaf sources at different levels. The available Mn content of the soil ranged from 57.1 ppm (at 2 per cent level of silver oak) to 162.5 ppm (at 2 per cent level of erythrina). No particular trend was observed with respect to level of application of leaf sources.

Fig.9. Decomposition of various leaf materials in the field



8 Decomposition of leaf materials in the field

The litter bag method was used for studying the rates of decomposition of different leaf materials in field soil conditions The mass remaining in the litter bags decreased with time for all species (Fig 9) The data on the quantity of leaf material remaining in the litter bags at different intervals were subjected to statistical analysis for the goodness of fit with exponential kinetic model as followed in the case of laboratory incubation experiment and described in the Section 7 1 The analyses of variance of the data are given in Appendix 9

The decomposition rate parameters and constants are furnished in Table 21 The half life values obtained for coffee erythrina and black pepper leaves were 40 44 and 53 days respectively

Table 21 Rates of decomposition of different leaf materials in field soil

Leaf material	Intercept	k (day ^{1})	$t_{\frac{1}{2}}$ (d)	R^2
Coffee	2 4171	0 0174**	40	0 832
Erythrina	2 4200	0 0158**	44	0 899
Garuga	1 3592	0 0113^{NS}		0 518
Silver oak	0 5147	0 0070^{NS}	-	0 085
Black pepper	2 7168	0 0131**	53	0 764

** Significant at 1 per cent level
* Significant at 5 per cent level
NS Not significant

Discussion

DISCUSSION

The results obtained from the pot culture experiment on the effect of application of organic sources on the growth and nutrition of black pepper vine as well as the results of incubation studies on the decomposition of applied organic sources to soil are discussed in this section

1 Biomass production

On an average leaf stem and root contributed about 53 32 and 15 per cent to the total biomass Application of leaves of coffee erythrina, garuga silver oak or black pepper to black pepper grown in pots had considerable effect on the growth of the vine as compared to control (Table 2) Each of these treatments increased the stem leaf and root production leading to an overall increase in biomass production Application of organic material enhanced the growth and biomass production by more than one hundred per cent in most of the treatments A comparison of these different sources did not indicate superiority of one over the other (Table 3) Nevertheless a differential response of the vine to the levels of application of different leaf materials was noticed The three levels of application of each of the leaf materials tried in this study were 1 2 and 3 per cent (on dry matter basis) with respect to the soil weight The response of the vine to erythrina and silver oak leaf treatments was more or less similar irrespective of the level of application Garuga leaf on the other hand increased the biomass production of the vine with increasing level of application Biomass production was doubled (17 59 g $plant^{-1}$) by the application of garuga leaf at 3 per cent compared to 1 per cent level of application (8 88 g $plant^{-1}$) Both coffee and black pepper leaf treatments increased the biomass production up to 2 per cent level of application beyond which there was a decrease

These results indicate three types of reactions of the vine to the application of organic sources, (a) a positive reaction to higher levels of application (b) a negative reaction with increasing level of application and (c) a neutral reaction showing neither positive nor negative trend in biomass production with increasing level of application The effect of garuga leaf treatment comes under the first type that of coffee and black pepper fall under the second type and that of erythrina and silver oak come under the third type This categorization implies that the nature of influence of different organic sources and the level of application on the growth of the vine is variable Black pepper vine is generally trailed on different tree species available in mixed cropping systems or on a particular tree species in pure stands In these situations, the growth pattern of the vine could be greatly influenced by the leaf litter(s) that decompose in the soil floor Of the tree species included in the present study <u>Erythrina indica</u> <u>Garuga pinnata</u> and <u>Grevilea robusta</u> (silver oak) are popular support trees for black pepper vine Coffee leaf was included in the study because in many of the pepper growing tracts especially in Wynad district of Kerala State the vine is grown mixed with coffee In such situations the decomposition of coffee leaf litter in the soil can influence the growth of the vine

The results generated from this study may be discussed in relation to the effect of litter fall in black pepper gardens The accumulation of fallen erythrina and silver oak leaves to the extent of 3 per cent with respect to soil may not have any adverse effect on the growth of the vine It is however not known whether further accumulation of the litter will alter this trend Similarly it cannot also be said whether accumulation of garuga leaves in the soil basin of the vine at more than 3 per cent level would continue to increase the growth of the vine The most significant observation in this respect is the supression of growth in vines receiving coffee leaves at rates above 2 per cent The growth improvement observed at 1 and 2 per cent levels of application (about 14 g dry matter plant ^{1}) came down to 8 76 g dry matter plant ^{1} at 3 per cent level of application This is very close to the growth observed in the control vines (6 16 g dry matter plant^{-1}) It is also surprising to note that the black pepper vines treated with its own leaves also showed a growth decline at higher levels of application although not to the same extent as in the case of coffee leaf treatment There is sufficient reason to suspect that the production of phytotoxic substances during the decomposition of these two materials may be responsible for the observed growth retardation in vines receiving these materials These materials contain tannins polyphenols etc Pearson (1977) reported that raw coffee contain about 9% tannins Geetha et al (1990) observed browning of the explants (shoot tips nodal and internodal segments leaves and roots) of black pepper because of the phenolic oxidation Allelopathic effects of phytotoxins such as tannins and polyphenols have been reported in rice fields (Chandramohan et al 1973) clover (Chang et al , 1969) inhibitory action of corn plant residue on wheat seedling growth (Guenzi and McCalla, 1966) rice residues (Kuwatsuka and Shindo 1973) There are several reports of allelopathic effects of decaying residues observed in crop plants (Chou and Lin 1976 Chou and Patric 1976 Lodhi, 1978 Tamura et al 1967 1969 Tang and Waiss, 1978 Segwal, 1986) Considering these aspects the growth retardation observed in the vines receiving coffee and black pepper leaf treatments could be possibly due to allelopathic effect exerted by the decaying materials

2 Nutrient removal

Application of the leaf materials irrespective of the source increased the concentrations of all the nutrients in plant parts The exceptions are the Fe content of the leaf and Mn content of the stem However the effect of different levels of application of different leaf sources was not similar (Tables 5 7 and 9) Significantly higher quantities of N P K Ca Mg S Fe and Mn were removed by the vines under organic treatments compared to the control vines (Table 11)

The highest rate of application of coffee leaf treatment suppressed the uptake of N P and K but not that of other nutrients The effect could be primarily due to the growth retardation of the vines rather than a decrease in the nutrient composition of the plant parts (Tables 2 and 5) The removal of other nutrients was however not affected by growth retardation as the vine tended to accumulate more of these nutrients in the leaf and stem

Plants under erythrina leaf treatment showed higher uptake of N P and K upto the 2 per cent level of application (Table 11) No differences were however noticed in the removal of other nutrients by the vine with increasing level of leaf application The greater uptake of N P and K by these vines can only be explained as a combined effect of dry matter production and nutrient accumulation in the vine tissues (Tables 2 and 5) It may also be seen from Table 18 that erythrina leaf is rich in N P and K Probably this would also have helped in greater uptake of these nutrients by the vines under this treatment

Application of garuga leaves increased the uptake of N P K, Ca and S with increasing levels (Table 11) Increased concentration of these nurients in the aerial parts of the vine as well as enhanced plant growth with increasing rate of application of garuga leaf would account for the observed trends in the uptake of these nutrients (Tables 2 5 and 7) In other three cases namely Mg Fe and Mn such an effect was not evident probably because of the lowering of the concentrations of these nutrients in the leaf and stem at higher rates of application (Tables 7 and 9) Although garuga leaf has fairly good concentrations of Mg and Fe (Table 18) its application was not effective to improve the absorption of these nutrients by the vine

In vines receiving silver oak leaf uptake of nutrients remained more or less unaffected by higher levels of application However two exceptions to this trend are the significant increase in removal of K and a significant decrease in removal of Mg at the highest level of application (Table 11) An increase in uptake of K and a decrease in uptake of Mg despite the lack of influence on biomass production could be due to the higher concentration of K and lower concentration of Mg in the plant parts at higher levels of the applied organic source (Tables 5 and 7)

When the vines were applied with the leaves of own species uptake of N increased upto 2 per cent level of application and decreased at higher rate of application Significant decreases at 3 per cent level of application were also observed in the uptake of K Ca and S (Table 11) indicating a close correspondence with its effect on biomass production (Table 2) rather than the nutrient composition of the plant parts (Tables 5 and 7)

An overall comparison of the five organic sources indicated that the uptake of K and Ca by the vine was greatly improved when leaves of the same species were applied as an organic source (Table 12) This could be mainly due to the higher contents of these two nutrients in black pepper leaf (Table 18)

The better performance of the vines receiving organic treat ments in terms of growth and nutrient removal compared to control plants is a reflection of the supplementation of the nutrients through this sources as could be evidenced from the nutrient composition of these organic sources (Table 18) More importantly the quantities of nutrients in the organics would have been slowly made available to the vines during their decomposition in the soil This contention is also supported by the higher nutrient status of the soil amended with organic sources as evidenced from the Tables 17 and 20

Strong positive relationships exist among foliar concent rations of several nutrients (Table 14) indicating their compli mentary or antagonistic relationships during absorption Positive correlations were seen between N and S P and K K and S Ca and Fe and Mg and Mn while negative relationship was seen in the case of P and Ca

3 Decomposition of organic materials in the soil

The results generated from the laboratory incubation study as well as from the field study using litter bag method indicated considerable differences in decomposition rates In this context it may be noted that the assessment of organic carbon content formed the basis of evaluation of decay rates in the laboratory experiment whereas in the field study it was the leaf mass remaining at different time intervals that was considered for the determination of decay rates The Walkley Black method used in the determination of organic carbon remaining in the soil essentially determines the oxidisable part of the organic matter Nevertheless theoritically the decay rates for different leaf materials should be more or less same for the laboratory incubation as well as for field incubation However the decay of the organic materials proceeded at very faster rate in the field than in the laboratory (Tables 19 and 21) On an average the $t_{\frac{1}{2}}$ values obtained for the laboratory incubation were 2 to 4 times higher than in the field conditions Indirectly it shows that the decay of the materials was extremely fast in the field The average rates of decomposit ion in the laboratory incubation study followed the increasing order garuga > erythrina > black pepper > coffee or silver oak

Summary

SUMMARY

An investigation on the growth and nutrition of black pepper (*Piper nigrum* L) as influenced by decaying litter materials in soil was conducted during 1991 92 at Radiotracer Laboratory College of Horticulture Vellanikkara The major objectives of the experiment were to assess the effect of soil application of various leaf materials on the growth and nutrition of black pepper, to determine the rates of decomposition of different leaf materials and to evaluate its effect on nutrient availability

In pot culture experiment with black pepper var Panniyur 1 was invariably used The leaves of *Coffea arabica* *Erythrina indica*, *Garuga pinnata* *Grevilea robusta* (silver oak) and *Piper nigrum* were used as organic sources A laboratory incubation study and a field evaluation were also carried out on the decomposition rates of various organic sources For chemical analysis of soil and plant samples spectrophotometric flame photometric and atomic absorption spectrometric methods were adopted

The salient findings from these studies are summarised below

Biomass production in black pepper was significantly increased following the incorporation of leaf materials into the soil compared to the control vines

Significant difference in root production was observed when the control vines were compared against the rest of the treatments taken together

Biomass production by the vine decreased at highest level of application of coffee and black pepper leaves whereas a reverse trend was observed in case of garuga leaf treatment However the rate of application of erythrina and silver oak leaves had no influence on the vine growth

The contributions of leaf stem and root to the total biomass production were 53 32 and 15 per cent respectively Leaf and stem production accounted for 62 and 38 per cent respectively of the shoot biomass

Significant increases were noticed in N P and K concentrations of leaf and stem of black pepper vine consequent to the application of leaf materials compared to control Leaf Mg concentration significantly increased between control and organic matter receiving vines In the case of S application of organic materials substantially improved its concentrations in the leaf and stem Iron content of stem and foliar Mn concentration increased in vines receiving organic treatments

Leaf recorded higher concentrations of all the nutrients as compared to stem except for phosphorus

The vine removed significantly higher quantities of N P K Ca Mg S Fe and Mn following soil incorporation of the organic materials as compared to the control vines

The highest rate of application (3 per cent) of coffee leaf suppressed the uptake of N P and K but not that of other nutrients This was attributed to allelopathic effect of the decomposing leaf material on the vine growth

The plants under erythrina leaf treatment showed higher uptake of N P and K upto the 2 per cent level of application

Application of garuga leaves increased the uptake of N P K Ca and S with increasing levels

In vines receiving silver oak leaf uptake of nutrients remained more or less unaffected by increasing level of application

When the vines were treated with its own leaves N uptake increased upto 2 per cent level of application and decreased at higher rate of application In case of K Ca and S uptake signifi cant decreases at the highest level (3 per cent) of application were recorded

A general comparison of the different organic sources indicated that they had more or less similar effect on the uptake of N P S, Fe and Mn Black pepper leaf application significantly increased the K and Ca uptake by the vines

The average nutrient removal by a six month old black pepper vine grown in pots to produce 11 19 g of shoot dry matter was 200 19 mg N 18 92 mg P 432 53 mg K 155 89 mg Ca 19 44 mg Mg 12 33 mg S 1517 µg Fe and 3546 µg Mn The nutrient removal by the experimental vines indicated the following decreasing order of K N Ca Mg P S Mn and Fe

The contributions of leaf to the removal of nutrients expressed in percentage were 87 31 78 43 76 82 75 31 66 20 65 88, 64 21 and 59 94 for Mn S N Mg Ca K Fe and P respectively

Significant relationships among the concentrations of some of the leaf nutrients were observed Positive correlations were obtained between N and S P and K K and S Ca and Fe and Mg and Mn The correlation between P and Ca was negative

Significant differences were observed in chemical characteristics of the soil at the end of the experiment both in pot culture and in laboratory incubation studies In general soil pH decreased following the incorporation of leaf materials Compared to control organic carbon content of the soil receiving different leaf materials was much higher There were significant increases in the availability of major and micronutrients as a result of application of leaves of different organic sources

In the laboratory incubation experiment in which organic carbon was estimated at different intervals of time to provide an index of decomposition the rate of organic carbon loss was the slowest in soil with coffee or silver oak as the organic source and fastest when the garuga leaf was the source The half life values for organic carbon loss in soil ranged from 91 to 193 days

In field decomposition study the half life values obtained for coffee erythrina and black pepper leaves were 40 44 and 53 days respectively

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* Original not seen

Appendix 1 Abstract of Anova

Dry matter production in black pepper vine (g plant ^{1}) as influenced by application of leaf materials

Source	df	Mean square				
		1	2	3	4	5
		Leaf	Stem	Shoot	Root	Total
Treatments	15	8 664**	3 775**	23 083**	0 864^{NS}	31 485**
Among the organic sources	4	3 122^{NS}	2 034^{NS}	9 467^{NS}	0 388^{NS}	13 207^{NS}
Control vs organic treatments	1	48 890**	14 317**	116 002**	2 844*	155 167**
Error	32	1 977	1 124	5 647	0 522	9 166

NS Not significant

** Significant at 1 per cent level

* Significant at 5 per cent level

Appendix 2 Abstract of Anova

N P and K concentrations (%) in the above ground parts of black pepper vine in relation to the application of different leaf materials

Source	df	Mean square					
		1	2	3	4	5	6
		Leaf N	Stem N	Leaf P	Stem P	Leaf K	Stem K
Treatments	15	0 956**	0 279**	0 0016**	0 0030**	0 203*	0 520**
Among the organic sources	4	1 546**	0 240 **	0 0030**	0 0013NS	0 154NS	0 430NS
Control vs organic treatments	1	6 771**	0 229*	0 0020**	0 0170**	0 878**	4 377**
Error	32	0 038	0 034	0 0003	0 0010	0 083	0 166

NS Not significant

** Significant at 1 per cent level
* Significant at 5 per cent level

Appendix-3 Abstract of Anova

Ca Mg and S concentration (%) in the above-ground parts of black pepper vine in relation to the application of different leaf materials

Source	df	Mean square					
		1	2	3	4	5	6
		Leaf Ca	Stem Ca	Leaf Mg	Stem Mg	Leaf S	Stem S
Treatments	15	0 0280**	0 015**	0 017**	0 0030**	0 0003*	0 0005**
Among the organic sources	4	0 0790**	0 035**	0 158**	0 0040**	0 0001 NS	0 0013**
Control vs organic treatments	1	0 0002 NS	0 005 NS	0 035**	0 0002 NS	0 0011**	0 0006**
Error	32	0 0040	0 004	0 004	0 0010	0 0001	0 00003

NS Not significant

** Significant at 1 per cent level

* Significant at 5 per cent level

Appendix 4 Abstract of Anova

Fe and Mn concentrations (ppm) in the above ground parts of black pepper vine in relation to the application of different leaf materials

Source	df	Mean square			
		1	2	3	4
		Leaf Fe	Stem Fe	Leaf Mn	Stem Mn
Treatments	15	2079 7^{NS}	2143 2	30706 7*	1355 0^{NS}
Among the organic sources	4	4557 8^{NS}	1355 5^{NS}	9311 8^{NS}	1457 8^{NS}
Control vs organic treatments	1	1430 9^{NS}	5281 0*	84953 0*	18 5^{NS}
Error	32	2223 4	835 4	14704 8	941 6

NS Not significant

** Significant at 1 per cent level

* Significant at 5 per cent level

Appendix 5 Abstract of Anova

Nutrient removal by black pepper vine (per plant) as influenced by the application of leaf materials

Source	df	Mean square							
		1	2	3	4	5	6	7	8
		N (mg)	P (mg)	K (mg)	Ca (mg)	Mg (mg)	S (mg)	Fe (µg)	Mn (µg)
Treatments	15	13012**	116**	42143**	4892**	82**	32**	518060*	2057992*
Among the organic sources	4	4901^{NS}	60^{NS}	17448*	4411**	90*	12^{NS}	613823^{NS}	931796^{NS}
Control vs organic treatments	1	84350**	513**	241402*	22879**	584**	187**	2977861*	18897948**
Error	32	2092	26	6037	996	26	10	241214	937123

NS Not significant

** Significant at 1 per cent level

* Significant at 5 per cent level

Appendix 6 Abstract of Anova

Chemical characteristics of the soil at the end of pot culture experiment as influenced by the application of various organic sources

Soil chemical characteristic	Mean square	
	1	2
	Treatments at 15 df	Error at 32 df
PH	0 051**	0 011
Organic carbon	0 074*	0 028
Available P	30 715**	1 862
Exchangeable K	0 133**	0 003
Exchangeable Ca	0 427**	0 047
Exchangeable Mg	0 133**	0 043
Available S	372 500**	71 752
Available Fe	5 197**	1 215
Available Mn	139 667**	34 714

** Significant at 1 per cent level
* Significant at 5 per cent level

Appendix-7 Abstract of Anova

Rates of decomposition of different organic matters in laboratory incubation experiment

Organic source		Mean square	
		1	2
		Regression at 1 df	Residual at 4 df
Coffee			
	C_1	0 20887**	0 00572
	C_2	0 10715^{NS}	0 01833
	C_3	0 20214**	0 00307
Erythrina			
	E_1	0 21258**	0 00348
	E_2	0 37815**	0 01756
	E_3	0 27924*	0 02857
Garuga			
	G_1	0 33943*	0 02720
	G_2	0 25289*	0 01232
	G_3	0 61427**	0 01433
Silver oak			
	S_1	0 23157**	0 00930
	S_2	0 17025**	0 00508
	S_3	0 20984**	0 00455
Black pepper			
	B_1	0 25395**	0 00679
	B_2	0 13950*	0 01610
	B_3	0 38356**	0 00548

NS Not significant

** Significant at 1 per cent level
* Significant at 5 per cent level

Appendix 8 Abstract of Anova

Chemical characteristics of the soil after 60 days of incubation as influenced by the application of various leaf materials

Soil chemical characteristic	Mean square	
	1	2
	Treatments at 14 df	Error at 15 df
pH	0 200**	0 016
Organic carbon	0 136**	0 007
Available P	7 423**	0 078
Exchangeable K	0 294**	0 002
Exchangeable Ca	0 329**	0 014
Exchangeable Mg	0 100**	0 022
Available S	411 372**	7 042
Available Fe	266 011**	45 440
Available Mn	1882 230NS	1854 057

NS Not significant
** Significant at 1 per cent level

Appendix 9 Abstract of Anova

Rates of decomposition of different leaf materials in field soil

Leaf material	Mean square	
	1	2
	Regression at 1 df	Residual at 5 df
Coffee	7 64903**	0 30903
Erythrina	6 32133**	0 14201
Garuga	3 21648^{NS}	0 59827
Silver oak	1 24925^{NS}	2 68665
Black pepper	4 29228**	0 26564

NS - Not significant

** Significant at 1 per cent level

GROWTH AND NUTRITION OF BLACK PEPPER AS INFLUENCED BY DECAYING LITTER MATERIALS IN SOIL

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

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ABSTRACT

An investigation on the growth and nutrition of black pepper (<u>Piper</u> <u>nigrum</u> L) as influenced by decaying litter materials in soil was conducted at the College of Horticulture Vellanikkara The black pepper variety Panniyur-1 was invariably used for the study

Biomass production in black pepper was significantly increased following the incorporation of organic materials into the soil compared to the control vines When the different levels of organic sources were compared total biomass production of the vine decreased at highest level (3 per cent) of application of coffee and black pepper leaves This was attributed to allelopathic effect of the decaying material There was a steady increase in biomass production with increasing level of garuga leaf application

Significant increases were noticed in the N P and K concentrations of leaf and stem Mg concentration of leaf S concent ration of leaf and stem Fe content of stem and foliar Mn content of the vine following the organic matter treatments as compared to control vines

The vine removed significantly higher quantities of N P K Ca Mg S Fe and Mn following the soil application of leaf materials as compared to the control vines

The average nutrient removal by a six month old black pepper vine to produce 11 19 g of shoot dry matter was 200 19 mg N 18 92 mg P, 432 53 mg K 155 89 mg Ca 19 44 mg Mg 12 33 mg S 1517 µg Fe and 3546 µg Mn The contribution of leaf to the total nutrient removal was more compared to that of stem

Significant increases in major and micronutrient availability in soil were noticed following the incorporation of leaf materials

On an average the rate of organic carbon loss in laboratory incubation was the slowest in soil with coffee or silver oak leaves as the organic source and was fastest when the garuga was the organic source The half life values for organic carbon loss varied from 91 193 days

The half life values obtained for coffee erythrina and black pepper leaves in field decomposition study were 40 44 and 53 days respectively