# Effect of application of organic materials on growth and foliar nutrient contents of black pepper (*Piper nigrum* L.)

C SIVA KUMAR & P A WAHID[1]
*Radiotracer Laboratory, College of Horticulture*
*Kerala Agricultural University*
*Vellanikkara, Thrissur - 680 654, India.*

ABSTRACT

The effect of soil application of organic materials (leaves of *Erythrina indica, Garuga pinnata, Grevilea robusta, Piper nigrum* and *Coffea arabica*) on growth and nutrition of black pepper vines (*Piper nigrum*) was studied in pot culture experiments. A substantial increase in growth and biomass production was noticed in vines treated with organic materials as compared to control. However, application of leaves of *C. arabica* and *P. nigrum* at higher rates suppressed growth of vines probably due to allelopathic effects of the decay products of these materials in the soil. The rates of decomposition of leaf materials in the soil varied considerably. Leaves of *C. arabica* and *G. robusta* were the most persistent while that of *G. pinnata* was least resistant to decomposition.

Key words: allelopathy, *Coffea arabica, Erythrina indica, Garuga pinnata, Grevilea robusta, Piper nigrum.*

## Introduction

Among the spice crops cultivated in India, black pepper (*Piper nigrum* L.) enjoys a unique position being the largest exported crop in terms of foreign exchange earnings. Kerala accounts for over 90 per cent of the black pepper production in the country. The black pepper vine is grown supported on trees (known as standards) such as *Erythrina indica* Lamk. (Indian coral tree), *Garuga pinnata* Roxb., *Grevilea robusta* A. Cunn. (silver oak) or on other tree species available in the garden. The growth of the vine could be influenced by the presence of standards through its allelopathic effects, competition for solar radiation, nutrients water, etc. The soil environment may also be altered by the decomposing litter fallen from the standards which in turn could influence the growth of the vine. No information is available on the rate of decomposition of fallen leaves from the standards and its influence on the growth and nutrition of the vine. The present study was

[1]Corresponding author

therefore undertaken with these objectives in view.

## Materials and methods

### *Pot culture experiment*

Laterite soil (Oxisol) was used in the experiment. Surface soil (0.25 cm depth) was collected, air-dried and sieved through a 2 mm mesh. Earthern pots of 35 cm height and 25 cm dia at the top (without drain holes) were filled with 4 kg soil per pot. Five organic sources, namely, leaves of *E. indica, Coffea arabica* L. (coffee), *G. pinnata,G. robusta* and *P. nigrum* were evaluated. These were selected because of their practical significance. *E. indica, G. pinnata* and *G. robusta* are commonly used as standards and hence decomposition of their leaf litter can influence vine growth. Since black pepper is also grown as a mixed crop in coffee plantations, *C. arabica* leaves were also included as one of the organic sources.

The leaf materials were dried and chopped into 1-2 cm size pieces and incorporated into the soil in pots separately at 1, 2 and 3 per cent of soil weight. Control pots without organic sources were also maintained. Each treatment was replicated thrice. The pots were arranged randomly on concrete benches inside a green house. Rooted black pepper (var. Panniyur-1) cuttings of uniform growth (with two leaves) were planted at the rate of one cutting per pot. The vines also received uniform doses of 100, 50 and 100 kg per ha of N, $P_2O_5$ and $K_2O$, respectively, during the second month after planting. Nitrogen was supplied through urea; phosphorus and potassium were supplied through analytical grade $KH_2PO_4$ and KCl, respectively. The vines were removed after 6 months and the dry weights of leaves, stems and roots were recorded after drying in a cross-flow air oven at 70°C.

### *Soil and plant analyses*

The dried leaf and stem samples were ground in a Wiley mill fitted with stainless steel blades and the powdered samples were analysed for N by macro-Kjeldahl method. P and K were estimated by colorimetry and flame photometry, respectively, following diacid digestion of the samples. The soil used in the experiment and the soil samples collected from each pot during crop removal were analysed for pH, organic carbon, available P (Bray-1 P) and exchangeable K (Jackson 1958).

### *Laboratory incubation experiment*

An incubation experiment was also conducted in the laboratory to study the kinetics of decomposition of leaf materials in soil. Oven-dried and powdered (40 mesh) leaves of the plant species were evaluated at 3 per cent level of application with two replications. The powdered leaf material (3g) was mixed well with 100 g soil (2-mm sieved) in a plastic bottle of 8 cm height and 6 cm dia. Sufficient numbers of such plastic bottles containing soil and leaf materials were maintained for each species at 60% WHC so as to allow withdrawl of duplicate sets at 0, 15, 30, 60, 90 and 120 days of incubation. At each interval, the organic carbon loss due to decomposition was assessed by determining the organic carbon content of the soil by Walkely-Black method (Jackson 1958). The rates of decomposition of the organic sources were determined mathematically by the method suggested by Olson (1963).

## Results and discussion

### *Biomass production*

Biomass production of the experimental vines was considerably increased following application of leaf materials (Table 1). Control vines had the poorest growth (6.16 g plant$^{-1}$). The growth of vines treated with different organic sources was influenced by the quantity of the applied material. The total biomass increased from 8.88 to 17.59 g plant$^{-1}$ in vines treated with *G. pinnata* leaves. A decrease from 14.61 g at 1 per cent level to 8.76 g plant$^{-1}$ at 3 per cent level was observed in the case of *C. arabica* leaves. When *P. nigrum* leaves were used, the growth of the vine increased to 17.56 g at 2 per cent level and then decreased to 12.39 g plant$^{-1}$ at the highest level of application. In the case of *E. indica, G. pinnata* and *G. robusta* leaf treatments, vine growth generally increased with increasing levels of application. Although there were significant differences between organic treatments and control, the differences among different leaf materials were not significant.

Significant increases were noticed in foliar concentrations of N, P and K consequent to application of leaf mate-

**Table 1. Dry matter production in black pepper as influenced by application of leaf materials**

| Leaf material | Rate of appln. (%) | Shoot | | | Root | Total |
|---|---|---|---|---|---|---|
| | | Leaf | Stem | Total | | |
| *Coffea arabica* | 1 | 7.50 | 4.67 | 12.17 | 2.44 | 14.61 |
| | 2 | 7.34 | 4.45 | 11.79 | 1.65 | 13.44 |
| | 3 | 4.93 | 2.83 | 7.76 | 1.00 | 8.76 |
| *Erythrina indica* | 1 | 6.60 | 3.35 | 9.95 | 2.39 | 12.34 |
| | 2 | 8.67 | 5.13 | 13.80 | 2.47 | 16.27 |
| | 3 | 7.23 | 4.21 | 11.44 | 1.56 | 13.00 |
| *Garuga pinnata* | 1 | 4.72 | 2.90 | 7.62 | 1.26 | 8.88 |
| | 2 | 6.88 | 4.72 | 11.60 | 2.05 | 13.65 |
| | 3 | 9.35 | 5.73 | 15.08 | 2.51 | 17.59 |
| *Grevilea robusta* | 1 | 6.00 | 3.64 | 9.64 | 1.72 | 11.36 |
| | 2 | 6.62 | 3.83 | 10.45 | 2.03 | 12.48 |
| | 3 | 8.36 | 4.48 | 12.84 | 2.20 | 15.04 |
| *Piper nigrum* | 1 | 8.76 | 5.11 | 13.87 | 2.64 | 16.51 |
| | 2 | 8.82 | 6.43 | 15.25 | 2.31 | 17.56 |
| | 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 |

Values are in g plant$^{-1}$

rials compared to control (Table 2). While a higher rate of application of *C. arabica* leaves tended to decrease leaf N, that of *E. indica* increased it. Among the organic sources, the lowest concentration of leaf N was observed in vines treated with *P. nigrum* leaves.

Soil incorporation of leaf materials significantly increased foliar P concentration. A comparison of different levels of treatments indicated that the increase in leaf P concentration occurred up to 2 per cent level of application in all cases except in vines treated with *E. indica* or *G. pinnata* leaves. 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 was recorded in vines treated with *G. pinnata* leaves and the lowest in vines treated with *G. robusta* leaves.

Foliar K levels of vines under organic treatments were considerably higher when compared to control. However, the effect of increasing levels of organic matter application was not marked except in the case of *C. arabica* and *E. indica* leaf treatments. Vines treated with *C. arabica* leaves at 3 per cent had the highest concentration of foliar K (4.44%) while the minimum (3.73%) was recorded in vines treated with *E. indica* leaves at 1 per cent.

**Table 2. Foliar N, P and K concentrations in black pepper in relation to application of leaf materials**

| Leaf material | Rate of appln. (%) | N | P | K |
|---|---|---|---|---|
| *Coffee arabica* | 1 | 3.19 | 0.146 | 3.94 |
| | 2 | 2.57 | 0.192 | 4.25 |
| | 3 | 2.48 | 0.146 | 4.44 |
| *Erythrina indica* | 1 | 2.33 | 0.150 | 3.73 |
| | 2 | 2.57 | 0.175 | 3.85 |
| | 3 | 2.71 | 0.167 | 4.38 |
| *Garuga pinnata* | 1 | 2.24 | 0.175 | 4.13 |
| | 2 | 2.36 | 0.194 | 4.31 |
| | 3 | 2.29 | 0.201 | 4.41 |
| *Grevilea robusta* | 1 | 1.90 | 0.142 | 3.79 |
| | 2 | 2.24 | 0.158 | 4.13 |
| | 3 | 2.00 | 0.125 | 4.06 |
| *Piper nigrum* | 1 | 1.57 | 0.138 | 4.16 |
| | 2 | 1.78 | 0.163 | 3.97 |
| | 3 | 1.71 | 0.167 | 4.29 |
| Control | | 0.71 | 0.129 | 3.56 |
| SEm ± | | 0.11 | 0.010 | 0.17 |
| CD (0.05) | | 0.32 | 0.028 | 0.49 |

Values indicate concentrations in %

*Changes in chemical properties of soil*

The soil used in the study was acidic in reaction (pH 5.7) with an organic carbon content of 1.05% and was low in major nutrients (available P 3.58 ppm and exchangeable K 0.27 cmol (+) $kg^{-1}$). Application of leaf materials had a variable effect on soil pH compared to control (Table 3). Soil pH decreased significantly following application of *C. arabica* leaves at 3 per cent level while it increased in soil receiving *G. robusta* leaves. Barring this, no regular trend was observed in changes of soil pH due to application of leaf materials. The organic carbon content of soil treated with different leaf materials was much higher compared to control. Available P and exchangeable K in the soil also increased substantially consequent to application of organic sources.

*Nutrient composition of leaf materials*

A comparison of nutrient concentrations in leaf materials indicated that *E. indica* leaves contained a very high concentration of N (4.07%) whereas, *G. robusta* had the least (1.96%) (Table 4). A similar trend was observed in the case of P also. The K content was highest in *C. arabica* leaves.

Black pepper vines are generally trailed on various tree species in mixed cropping systems and in pure stands. In these situations, the growth pattern of vines could be greatly influenced by the

**Table 3. Chemical characteristics of soil at the end of pot culture experiment as influenced by application of leaf materials**

| Leaf material | Rate of appln. (%) | pH | Organic carbon (%) | Available P (ppm) | Exchangeable K (cmol (+) $kg^{-1}$) |
|---|---|---|---|---|---|
| *Coffea arabica* | 1 | 5.58 | 1.22 | 7.05 | 0.393 |
| | 2 | 5.48 | 1.45 | 12.57 | 0.577 |
| | 3 | 5.22 | 1.48 | 10.76 | 0.963 |
| *Erythrina indica* | 1 | 5.47 | 1.16 | 6.76 | 0.323 |
| | 2 | 5.35 | 1.29 | 11.34 | 0.440 |
| | 3 | 5.47 | 1.42 | 18.86 | 0.707 |
| *Garuga pinnata* | 1 | 5.55 | 1.11 | 11.24 | 0.287 |
| | 2 | 5.35 | 1.28 | 9.29 | 0.500 |
| | 3 | 5.58 | 1.47 | 11.00 | 0.520 |
| *Grevilea robusta* | 1 | 5.45 | 1.22 | 7.24 | 0.287 |
| | 2 | 5.52 | 1.36 | 8.57 | 0.343 |
| | 3 | 5.62 | 1.46 | 10.10 | 0.483 |
| *Piper nigrum* | 1 | 5.68 | 1.25 | 7.43 | 0.347 |
| | 2 | 5.25 | 1.55 | 6.86 | 0.633 |
| | 3 | 5.57 | 1.49 | 10.29 | 0.833 |
| Control | | 5.50 | 1.01 | 5.62 | 0.200 |
| SEm ± | | 0.06 | 0.10 | 0.79 | 0.030 |
| CD (0.05) | | 0.17 | 0.29 | 2.28 | 0.086 |

**Table 4. Nutrient composition of leaf materials**

| Leaf material | N | P | K |
|---|---|---|---|
| *Coffea arabica* | 3.43 | 0.150 | 2.63 |
| *Erythrina indica* | 4.07 | 0.275 | 2.13 |
| *Garuga pinnata* | 2.96 | 0.213 | 1.84 |
| *Grevilea robusta* | 1.96 | 0.075 | 1.25 |
| *Piper nigrum* | 2.64 | 0.125 | 2.41 |

Values indicate % composition

leaf litter that decomposes on the soil floor. Black pepper vines treated with *C. arabica* or its own leaves showed a growth decline at higher levels of application probably due to production of phytotoxic substances during the decomposition of these two materials which contain tannins, polyphenols etc. Pearson (1977) reported that raw coffee contains about 9% tannins. Geetha *et al.* (1990) observed browning of explants (shoot tips, nodal and internodal segments, leaves and roots) of black pepper because of phenolic oxidation. Allelopathic effects of phytotoxins such as tannins and polyphenols have been reported in many plants (Chandramohan, Purushothaman & Kothandaraman 1973; Chang *et al.* 1969; Guenzi & McCalla 1962). There are several reports of allelopathic effects of decaying residues in crop plants (Chou & Lin 1976; Tang & Waise 1978; Segwal 1986). Thus the growth retardation observed in vines receiving *C. arabica* and *P. nigrum* leaf treatments could be possibly due to the allelopathic effect exerted by the decaying leaves.

The better performance of vines receiving organic treatments in terms of growth and nutrient removal compared to control plants is a reflection of the supplementation of nutrients through these sources. Although only NPK nutrients were considered in this study, other nutrients as well as some of the products of decomposition might also have exerted a beneficial effect on the growth of vines. More importantly, the nutrients in the organics would have been made slowly available to the vines, during their decomposition in the soil leading to their better utilisation.

*Decomposition of leaf materials in soil under laboratory conditions*

The data on organic carbon remaining in the soil at different intervals following application of various leaf materials were subjected to regression analysis based on the exponential model suggested by Olson (1963) : $x/x_0 = e^{-kt}$, where x is the organic carbon remaining at time t, $x_0$ is the organic carbon content at time zero, e is the base of the logarithm, k is the decomposition rate constant and t is time. The goodness of fit of the kinetic data to this model was tested statistically (Table 5). Very high $R^2$ values were obtained for the regression equations describing the decomposition of the litter materials in the soil. The half-life values computed from the rate constants indicated that decomposition of *G. pinnata* leaves was the most rapid with a half-life of 91 days. The most persistent among the organic

**Table 5. Rates of decomposition of leaf materials in soil**

| Leaf material | Intercept | k ($d^{-1}$) | Half-life (d) | $R^2$ |
|---|---|---|---|---|
| *Coffea arabica* | 0.8231 | 0.0043** | 161 | 0.943 |
| *Erythrina indica* | 0.8290 | 0.0051* | 136 | 0.710 |
| *Garuga pinnata* | 0.9685 | 0.0076** | 91 | 0.915 |
| *Grevilea robusta* | 0.8936 | 0.0044** | 158 | 0.920 |
| *Piper nigrum* | 0.9566 | 0.0060** | 116 | 0.946 |

* Significant at 5% level
** Significant at 1% level

materials were *C. arabica* and *G. robusta* leaves.

## References

Chandramohan D, Purshothaman D & Kothandaraman R 1973 Soil phenolics and plant growth inhibition. Pl. Soil 39 : 303-308.

Chang C F, Suzuki A, Kumai S & Tamura S 1969 Chemical studies on clover sickness. II. Biological functions of isoflavonoids and their related compounds. Agric. Biol. Chem. 33 : 398-408.

Chou C H & Lin H J 1976 Autotoxication mechanisms of *Oryza sativa*. I. Phytotoxic effects of decomposing rice residues in soil. J. Chem. Ecol. 2 : 353-367.

Geetha C K, Nazeem P A, Lissamma J & Sudhadevi P K 1990 *In vitro* callus induction in black pepper. Indian Cocoa, Arecanut & Spices J. 15 : 34-36.

Guenzi W & McCalla T 1962 Inhibition of germination and seedling development by crop residues. Soil Sci. Soc. Amer. Proc. 26 : 456-458.

Jackson M L 1958 Soil Chemical Analysis. Prentice Hall of India Ltd., New Delhi.

Olson J S 1963 Energy storage and the balance of producers and decomposers in ecological systems. Ecology 44 : 322-331.

Pearson D 1977 The Chemical Analysis of Foods 17th Edn. Chemical Publishing Co. Inc., New York.

Segwal S S 1986 Allelopathic effect of leaf leachate of biul (*Grewia optiva*). Research and Development Reporter, Himachal Pradesh Krishi Vishwa Vidyalaya, Palampur 3 (2) : 93-94.

Tang C S & Waise A C 1978 Short-chain fatty acids as growth inhibitors in decomposing wheat straw. J. Chem. Ecol. 4 : 225-232.