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Phenylalanine Ammonia Lyase and Total Phenol Content in Resistant Banana to *Pratylenchus coffeae*

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ABSTRACT: The biochemical alterations in resistance banana accessions showed that relatively higher Phenylalanine Ammonia Lyase (PAL) activity than the susceptible ones indicating the inherent higher content of PAL in resistant accessions. The higher activity of this enzyme in resistant accessions *viz.*, Karthobiumtham, *M. balbisiana*, Kanai Bansi, Bhimkol, Athiakol, Aittakol, Kechulepa was negatively correlated with lesion index of roots and corm. Increase in phenol content and enzyme activities were negatively related with the degree of infestation. In the present study, total phenol estimated in roots of banana genotypes showed that these compounds were higher in resistant accessions than susceptible ones.

Key words: Banana, root lesion nematode, phenylalanine ammonia lyase activity, total phenol, resistance mechanism

The losses due to infection by nematodes in bananas and plantains vary depending on the extent of infection and the ability of the cultivars to resist or tolerate infection. Variation with respect to cultivar susceptibility has been well documented in numerous studies (Gowen *et al.*, 1998; Pinochet *et al.*, 1988; Van den Bergh *et al.*, 2000). Plants show a variety of responses when they attempt to resist the attack by pathogens. When these responses are successful and prevent or inhibit nematode growth, the plant is considered to have complete or fully functional resistance. Most of this resistance is found in hypersensitive type of responses that involve changes in enzyme activity, phenol metabolism and deposition of the newly synthesized material in cell walls and regulation of free radical O_2 (Ganguly & Dasgupta, 1980; Zacheo *et al.*, 1995).

Several researchers have emphasized the role of phenols as an expression of defense mechanism by the host plants (Bajaj *et al.*, 1983; Bleve-Zacheo *et al.*, 1990). The phenolic compounds are the best known factors involved in susceptible-resistance response.

The present investigations on banana (*Musa* spp.) were therefore carried out to identify resistant lines against *Pratylenchus coffeae* and to understand the mechanism of nematode resistance in banana.

MATERIALS AND METHODS

Ten diploids and 49 triploids belonging to the *Eumusa* section, comprising of wild and cultivated banana accessions collected from different parts of India and maintained in the germplasm bank of the Crop Improvement division, NRCB, were studied at the experimental farm of the National Research Centre for Banana (NRCB), Tiruchirapalli during 2004-06. Healthy banana suckers of uniform size and weight (750 g) were collected and immersed in water at 55°C for 15 min and used as starting material. They were then planted in cement pots containing 20 kg of pot mixture (red soil: sand: farm yard manure-2:1:1), sterilized with formaldehyde (4%). The soil was watered to field capacity. The individual pots were labeled with name of the genotype, genomic status and arranged in a factorial completely randomized design (FCRD) with five replications. Uninoculated controls were included in the experiment as comparison to study the sensitivity of the genotypes.

Preparation and maintenance of nematode cultures and inoculation of banana plants with *Pratylenchus coffeae*

Healthy banana corms of cv. Nendran were selected and planted at the rate of one per pot, filled with autoclaved pot mixture consisting of sand, red soil and FYM mixed in equal proportions. Roots infested with *P. coffeae* were collected from infested field of banana, washed in water, cut into small bits and processed in a warring blender. The nematodes were extracted and the nematode suspension was then poured into the rhizosphere of the plants after the emergence of roots. Banana cultivars maintained in the pots were inoculated with infective juveniles of root-lesion nematode, *P.coffeae* @ 1,000 nematodes/pot, respectively in the holes made around the rhizosphere of the plants after the emergence of roots i.e. at 45 DAI. After inoculation the soil was lightly watered. Biochemical estimation was done at 90th day after inoculation (DAI).

Total phenol content was estimated by Folin Ciocalteau method (Malik & Singh, 1980). The PAL assay was conducted as per the method described by Ross & Soderoff (1992). The assay mixture containing 10 ml of enzyme, 500 ml of 50 mM Tris HCl (PH 8.8) and 600 ml of 1 mM L-phenylalanine was incubated for 60 min. The reaction was arrested by adding 2 N HCl. Later 1.5 ml of toluene was added, vortexed for 30 sec, centrifuged (1000 rpm, 5 min) and toluene phase was measured at 290 nm against the blank of toluene. Standard curve was drawn using graded amounts of cinnamic acid in toluene and the enzyme activity was expressed as nmoles of cinnamic acid /min/g fresh tissue.

Two separate experiments were conducted for diploid and triploid accessions, based on a factorial completely randomized design, with five replicates for each genotype. The data recorded were subjected to statistical scrutiny by analysis of variance (ANOVA) using the AgRes statistical software (1994, Pascal International Software Solutions). Conclusions were drawn from the results obtained from the package.

RESULTS

The PAL activity differed significantly between the accessions, treatments and interaction (Table 1 and 2).

The diploid accession *M. balbisiana* (23.3 units/ min/g) registered the highest phenylalanine ammonia lyase activity, while the lowest was observed in Elakkiebale. The uninoculated plants (control) registered the lowest phenylalanine ammonia lyase activity of 15.0 units/min/g irrespective of the accessions screened. In nematode inoculated plants, phenylalanine ammonia lyase registered the highest activity in *M. balbisiana* (28.90 units/min/g fresh weight) followed by Bhimkol (28.00 units/min/g). The percentage increase of phenylalanine ammonia lyase activity over control was more in the genotype *M. balbisiana* (64.47 per cent).

Among the various triploid accessions screened, Jahaji (9.9 units/min/g) registered the lowest phenylalanine ammonia lyase activity (Table 2) while the highest was observed in Chinali (22.2 units/min/g). Among the treatments, the inoculated plants recorded the highest PAL activity of 17.9 units/min/g. Chinali recorded the highest PAL activity of 25.8 units/min/g while the lowest activity was recorded in Jahaji and Longol Local. The percentage increase of phenylalanine ammonia lyase activity over control was more in the genotype Karthobiumtham.

Nematode infestation increased the activity of PAL in all the banana accessions tested and the differences were significant.

The total phenol content of the banana accessions was estimated in roots and the results showed that there was a significant variation among the accessions (Table 1 and 2).

Among the diploid accessions screened, the highest total phenol content was noticed in *M. balbisiana* (11.5mg/g). Among the treatments, the nematode inoculated plants recorded the maximum phenol content of 11.0 mg/g. The total phenol content recorded the highest value of 14.6 mg/g of roots in *M. balbisiana* when infected.

Table 1. Phenylalanine ammonia lyase activity (mg/g) and total phenol content in diploid banana accessions inoculated with *P. coffeae*

		Phenylalanine ammonia lyase activity (mg/g)				Total phenol content (mg/g)			
		T_1-Ctrl	T_2-Inoc	A Mean	Inc. %	T_1-Ctrl	T_2-Inoc	A Mean	Inc. %
1.	Kanai Bansi	17.0	27.6	22.3	62.23	8.0	13.7	10.9	71.12
2.	Aktoman	13.8	20.8	17.3	50.68	7.4	11.7	9.6	57.92
3.	Elakkiebale	11.7	17.1	14.4	46.06	5.6	8.5	7.1	52.64
4.	Manguthamng	13.0	17.4	15.2	34.23	4.5	6.3	5.4	39.12
5.	Kechulepa	12.7	20.6	16.7	62.44	6.4	11.0	8.7	71.36
6.	Manohar	13.9	18.8	16.4	35.32	4.7	6.6	5.7	40.36
7.	*M. balbisiana*	17.6	28.9	23.3	64.47	8.4	14.6	11.5	73.68
8.	Athiakol	16.0	26.3	21.2	64.40	7.6	13.2	10.4	73.60
9.	Bhimkol	17.5	28.0	22.8	60.06	7.9	13.3	10.6	68.64
10.	Aittakola	16.3	25.5	20.9	56.35	6.8	11.2	9.0	64.40
	T Mean	15.0	23.1		54.00	6.7	11.0		64.18
		A	T	AxT		A	T	AxT	
	CD (P=0.05)	0.556	0.248	0.787		0.264	0.118	0.374	

The highest total phenol content was observed in the triploid accession Karthobiumtham (12.8mg/g). The uninoculated plants (control) registered the lowest total phenol content of 5.7 mg/g. Total phenol content varied from 3.6 to 9.2 mg/g of fresh root in accessions Manjahaji and Karthobiumtham maintained as control. In the nematode inoculated plants, the range was between 5.3 and 16.4 mg/g.

The total phenol in the roots of the banana accessions studied indicated a positive response due to nematode infestation and was more as compared to uninoculated banana roots.

DISCUSSION

Phenylalanine ammonia lyase is the most important enzyme in the synthesis of phenolics, phytoalexin and lignin. Hence it is considered as the most important enzyme in disease resistance. Lignin and wall bound phenolics are synthesized in the phenylpropanoid pathway. PAL is the first enzyme in the phenylpropanoid pathway and thus, PAL is involved in the defense mechanism of the plant. The enzyme estimated in the current investigation showed that relatively resistant accessions possessed higher PAL activity than the susceptible ones indicating the inherent higher content of PAL in resistant accessions. The higher activity of this enzyme in resistant accessions *viz.*, Karthobiumtham, *M. balbisiana*, Kanai Bansi, Bhimkol, Athiakol, Aittakol, Kechulapa was negatively correlated with lesion index of roots and corm.

Devarajan & Seenivasan (2002) observed that inoculation of *M. incognita* increased the polyphenol oxidase (catechol oxidase) activity in banana. Increased activity of peroxidase in tomato and phenylalanine ammonia lyase in brinjal was positively correlated with nematode resistance (Rajasekar *et al.,* 1997; Sirohi & Dasgupta, 1993).

Besides phytoalexins, most of the plants synthesis toxic compounds like phenols, proline and lignin as part of the normal development and are called phytoanticipins (Van Etten *et al.,* 1995). Their roles in resistance mechanism have been reported earlier by many workers (Reuveni *et al.,* 1992; Fogain & Gowen, 1996; Sarah *et*

Table 2. Phenylalanine ammonia lyase activity (mg/g) and total phenol content in triploid banana accessions inoculated with *P. coffeae*

		Phenylalanine ammonia lyase activity (mg/g)				Total phenol content (mg/g)			
		T_1-Ctrl	T_2-Inoc	A Mean	Inc. %	T_1-Ctrl	T_2-Inoc	A Mean	Inc. %
1.	BharatMoni	14.3	20.2	17.3	41.1	65.4	7.9	6.7	47.04
2.	Jahaji	8.3	11.4	9.9	36.79	5.9	8.4	7.2	42.04
3.	Manjahaji	9.9	13.9	11.9	40.25	3.6	5.3	4.5	46.00
4.	Barjahaji	10.6	14.4	12.5	35.53	4.4	6.2	5.3	40.60
5.	Honda	10.0	13.9	12.0	39.10	5.9	8.7	7.3	47.12
6.	Nendrapadathi	12.9	18.2	15.6	41.23	4.8	6.9	5.9	44.68
7.	Krishnavazhai	12.7	17.8	15.3	40.25	6.2	9.1	7.7	46.00
8.	Vannan	9.7	13.4	11.6	38.22	6.0	8.6	7.3	43.68
9.	Chinali	18.6	25.8	22.2	38.50	5.9	8.5	7.2	44.00
10.	Kaali	11.8	16.0	13.9	35.29	5.4	7.6	6.5	40.34
11.	Raithali	10.9	14.7	12.8	34.65	5.9	8.2	7.1	39.60
12.	Digjowa	15.4	20.4	17.9	32.55	3.9	5.4	4.7	37.20
13.	Malbhog	11.7	17.1	14.4	46.10	5.0	7.6	6.3	52.68
14.	Saapkal	14.6	19.8	17.2	35.28	7.2	10.1	8.7	40.32
15.	Honda	9.6	13.3	11.5	38.26	6.6	9.5	8.1	43.72
16.	Digjowa	11.2	15.4	13.3	37.66	6.8	9.7	8.3	43.04
17.	Jatikal	13.2	19.5	16.4	47.95	5.6	8.7	7.2	54.80
18.	Cheenichampa	12.6	17.2	14.9	36.75	4.7	6.7	5.7	42.00
19.	Dasaman	10.4	14.7	12.6	41.30	6.0	8.8	7.4	47.20
20.	Thiruvanan-thapuram	13.6	20.3	17.0	49.40	6.8	10.6	8.7	56.46
21.	Borchampa	9.6	13.0	11.3	35.60	4.3	6.0	5.2	40.68
22.	Krishnasagar	12.5	18.0	15.3	43.96	5.4	8.1	6.8	50.24
23.	Dudhsagar	16.0	23.6	19.8	47.78	6.1	9.4	7.8	54.60
24.	Sabri	9.8	13.3	11.6	35.56	5.6	7.9	6.8	40.64
25.	Dinamalakol	12.6	17.5	15.1	39.19	6.3	9.1	7.7	44.78
26.	Malai Kali	16.0	23.5	19.8	46.90	7.5	11.5	9.5	53.60
27.	Kait Long	12.7	19.1	15.9	50.75	5.5	8.7	7.1	58.00
28.	Karthobiumtham	14.7	24.8	19.8	68.74	9.2	16.4	12.8	78.56
29.	Deshi Kadali	13.8	21.1	17.5	53.20	5.2	8.4	6.8	60.80
30.	Agnimalbhog	12.6	19.3	16.0	52.89	4.5	7.2	5.9	60.44
31.	Kait Khullunq	11.7	17.3	14.5	48.24	7.6	11.8	9.7	55.14

Contd.....

		Phenylalanine ammonia lyase activity (mg/g)				Total phenol content (mg/g)			
		T_1-Ctrl	T_2-Inoc	A Mean	Inc. %	T_1-Ctrl	T_2-Inoc	A Mean	Inc. %
32.	Nutepong	13.7	19.8	16.8	44.45	5.6	8.4	7.0	50.80
33.	Kachkel	13.0	19.0	16.0	46.48	6.4	9.8	8.1	53.12
34.	Ankur -II	12.6	21.0	16.8	66.50	4.3	7.6	6.0	76.00
35.	Kait Shjeng	12.7	17.3	15.0	35.91	6.8	9.6	8.2	41.04
36.	Wild Hill	11.7	16.5	14.1	40.95	7.6	11.2	9.4	46.80
37.	Longol Local	8.5	11.4	10.0	33.95	4.0	5.6	4.8	38.80
38.	Therahaw	10.3	13.6	12.0	32.20	4.5	6.2	5.4	36.80
39.	Therahaw	11.5	15.4	13.5	34.16	4.4	6.1	5.3	39.04
40.	Nuzzat	14.5	21.1	17.8	45.50	6.6	10.0	8.3	52.00
41.	Veneetu Mannan	13.8	19.5	16.7	40.95	4.9	7.2	6.1	46.80
42.	Ankur-I	14.3	19.4	16.9	35.56	4.9	6.9	5.9	40.64
43.	Garomoina	15.6	21.6	18.6	38.40	5.1	7.3	6.2	43.88
44.	Bersain	10.8	14.6	12.7	35.56	4.9	6.9	5.9	40.64
45.	Gera	14.6	21.6	18.1	47.74	4.8	7.4	6.1	54.56
46.	Pordu	13.8	20.4	17.1	47.96	5.3	8.2	6.8	54.82
47.	Kothia	12.9	20.0	16.5	54.74	6.0	9.8	7.9	62.56
48.	Chakia	14.6	20.7	17.7	42.00	7.2	10.7	9.0	48.00
49.	Beula	15.0	21.9	18.5	46.06	6.5	9.9	8.2	52.64
	T Mean	12.6	17.9	42.06		5.7	8.4	47.37	
	Pisang Lilin	17.8	27.8		56.21	7.5	12.3		64.24
	Nendran	10.2	13.9		36.75	6.3	8.9		42.00
		A	T	AxT		A	T	AxT	
	CD (P=0.05)	0.436	0.087	0.617		0.208	0.041	0.295	

al., 1999). It is an established fact that in plant diseases where necrosis is involved, phenolics play a vital role (Wallace, 1961). Accumulation of phenolic compounds in diseased host plant tissue is considered to be due to the act of plant as an attempt to limit the development of pathogen.

In the present investigation, to find the biochemical basis for resistance in banana accessions, estimation of phenols and enzymes was carried out. Increase in phenol content and enzyme activities were negatively related with the degree of infestation. In the present study, total phenol estimated in roots of banana genotypes showed that these compounds were higher in resistant accessions than susceptible ones. According to Mateille (1994), these phenolic cells have a role in resistance in banana roots. Increase in concentration of phenols following infection with nematodes was reported by Ganguly & Dasgupta (1984) in tomato.

Vidhyasekaran (1988) described the occurrence of many kinds of phenolics in plants. Among them, total phenols play a unique role in response to pathogen and nematode infection. The results of the present study

revealed a significant increase in phenol content in the resistant and tolerant accessions *vis-a-vis* susceptible ones. Similar findings were observed by Fogain & Gowen (1996) and Krishnamoorthy (2002) for nematode resistance in banana. The accumulation of phenol may be due to the excess production of hydrogen peroxide by increased respiration (Farkas & Kiraly, 1962) or due to the activation of hexose monophosphate (HMP) shunt pathway, acetate pathway and release of bound phenols by hydrolytic enzymes (Goodman *et al.*, 1967).

Mateille (1994) found that higher number of cells with phenolic contents on the relatively less susceptible Gros Michel compared to the susceptible Poyo. Fogain (1996) and Valette *et al.* (1997) also reported higher amount of phenolics in the resistant genotype Yangambi Km 5 of banana whereas Wuyts *et al.* (2005) had given a contradictory report.

Increase in free phenols following infection with nematodes was also reported by Ganguly & Dasgupta (1984) in tomato, Wuyts *et al.* (2005) in banana, Bajaj *et al.* (1985) in tomato, Shukla & Chakraborthy (1988) in tobacco and Muzzafera *et al.* (1989) in coffee. Such stimulated production of phenolics following the invasion of nematodes, is a physiological process in host-pathogen interaction and is probably due to increase in activities of enzymes such as polyphenol oxidase and peroxidase.

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