PHYTOPATHOLOGICAL NOTES

Postinfection Changes in Chemical Compounds of Lemons Caused by Phytophthora citrophthora

Eliahou Cohen and Mina Schiffmann-Nadel

Plant Pathologist and Professor of Plant Pathology, respectively, Volcani Institute of Agricultural Research, Bet Dagan, Israel.

Contribution of The Volcani Institute of Agricultural Research, Bet Dagan, Israel, Journal Series Paper No. 1960-E.

The authors wish to express their thanks for advice and help in analytical tests to Anna Rajzman and for chromatography tests to A. Cohen.

ABSTRACT

Chemical changes in lemons infected by *Phytophthora citrophthora* include a noticeable reduction in the reducing and nonreducing sugar content, an increase of organic acids in the peel and a decrease in the juice, and a considerable decrease in ascorbic acid in the infected fruit as a whole. The total amount of free amino acids remains unchanged. Ethanol and methanol are present in markedly increased amounts. No change in the amount of essential oil present in the peel is found in infected fruit.

Phytopathology 62:1361-1362.

Additional key words: Citrus limon.

Chemical changes due to fungi have been studied in tissues of different plant organs, but relatively few studies have been carried out with fruits. Some studies have been reported on chemical changes caused by different fungal infections in guava, papaya, and banana (3), tomato (4), grape (12), and Moshambi orange (11) fruits. The present study is concerned with some of the chemical changes which occur in lemon (*Citrus limon* [L.] Burm.) when infected with *Phytophthora citrophthora* (Sm. & Sm.) Leonian.

Chemical analyses were carried out on juice from the pulp, and on aqueous extracts of the peel, flavedo, and albedo separately, prepared according to Horwitz (5). Determinations of chemical constituents were conducted according to different methods, sugars (7), organic acids expressed as citric acid (5), ascorbic acid (2), and free amino acids (formol number) (13). Additional separation and identification of sugars, organic acids, and amino acids from albedo, flavedo, and juice were done by paper chromatography. Ethyl and methyl alcohols from juice were analyzed by gas chromatography. Essential oil distilled from the fruit peel was determined according to the method of Samish & Cohen (10). All chemical examinations were repeated 4 times during the season: in July, August, September, and October. Inoculated fruits were incubated at 20 C. Symptoms of rot were evident after 5 or 6 days. Chemical analyses were made when rot developed on almost the whole fruit, 10 days after inoculation. Precautions were taken to prevent the development of organisms other than *P. citrophthora* on the inoculated fruit. All fruit before inoculation with *P. citrophthora* were washed with cotton dipped in alcohol. The inoculation was made by dipping the fruit in a spore suspension. Plating from rotten peel and pulp did not show any secondary organism.

For controls, the uninfected fruit was held for 10 days at 20 C.

Chemical changes in lemons infected by *P. citrophthora* were similar in all experiments; therefore, only the data of one experiment (October) are presented herein. In the diseased fruit, a noticeable reduction in the amount of reducing and nonreducing sugars is apparent (Table 1).

Paper chromatography revealed a lack of glucose and the presence of pentose in the diseased fruit. This decrease in sugars in the infected lemon is likely to be related to the considerable increase in respiration rate in fruit infected with *P. citrophthora*. McCombs & Winstead (8) found a reduction in sugars in cucumber fruits infected with *Pythium aphanidermatum*. Gladilovic & Drel' (4) and Kapoor & Tandon (6) noted that tomato fruits infected with *Phytophthora infestans* and *Drechslera australiense*, respectively, also had a reduced sugar content, whereas Ghosh et al. (3) found this to be true for guava, papaya, and banana fruits infected with various pathogenic fungi. On the other hand, in tomato fruit diseased with

TABLE 1. Chemical changes in lemon fruits infected by *Phytophthora citrophthora*

Fruit part examined	State of fruit	pH	Organic acids, %	Ascorbic acid, mg/100 g	Formol no., %	TSS[a] %	Total sugars, %	Reducing sugars, %	Nonreducing sugars, %
Flavedo	Infected	3.6	1.3	3.7	5.00	6.1	0.6	0.5	0.09
	Noninfected	4.8	0.7	62.1	5.00	6.1	2.6	2.3	0.24
Albedo	Infected	3.5	1.4	3.7	5.00	4.1	0.9	0.4	0.47
	Noninfected	5.1	0.4	37.3	5.00	6.2	10.2	5.5	4.51
Juice	Infected	2.8	4.8	33.5	2.75	8.7	1.9	1.3	0.52
	Noninfected	2.5	4.8	55.6	2.37	9.2	2.0	1.6	0.38

[a] Total soluble starch.

Phytophthora palmivora, Akinrefon (1) found no decrease in sugars.

Infected fruit showed some increase in organic acids in the peel, but a decrease was observed in the juice (Table 1).

Paper chromatography revealed some increase in malic acid content in the peel and a decrease in citric acid in the juice. A decrease in organic acids such as citric, malic, and tartaric acids has been observed in grapes infected with *Diplodia viticola* (12).

A considerable loss in ascorbic acid in infected fruit was found, and more markedly in the peel than in the juice. Similarly, a decrease in ascorbic acid was noted in tomato fruit infected with *P. infestans* (4).

The total amount of the free amino acids was unchanged. Paper chromatography showed that in all parts of the diseased fruit, γ amino butyric acid and asparagine were present in greater amounts than in sound fruit, whereas proline decreased; as also was found in Moshambi oranges infected with *Botryodiplodia theobromae* (11), where the proline content falls to zero.

A marked rise in the levels of alcohols was found in the juice of infected fruit; ethanol contents ranged from 0.73 to 1.43 mg/ml and methanol from 0.38 to 0.60 mg/ml. In healthy fruits, only traces of these alcohols were found. The increase of alcohols in infected lemon may indicate some disorders in the metabolism of the infected tissue. An increase of ethyl alcohol was also found in onion bulbs affected by various fungi during storage (9).

Essential oils in the peel of infected and uninfected fruit were in the range of 6.12 to 6.32 $\times$ 10^3 ml/cm^2.

LITERATURE CITED

1. AKINREFON, O. A. 1969. Biochemical studies on plant tissues infected by Phytophthora palmivora (Butl.) Butl. Ann. Appl. Biol. 63:303-313.
2. COHEN, A. 1953. The effect of different factors on the ascorbic acid content in citrus fruits. I. The dependence of the ascorbic acid content of the fruit on light intensity and on the area of assimilation. Bull. Res. Cons. Israel 3:159-170.
3. GHOSH, A. K., R. N. TANDON, K. S. BILGRAMI, & M. P. SRIVASTAVA. 1964. Studies on fungal diseases of some tropical fruits. II. Post-infection changes in the sugar contents of some fruits. Phytopathol. Z. 50:283-288.
4. GLADILOVIC, B. R., & R. I. DREL'. 1965. The effect of late blight infection on the chemical composition of tomatoes. Zap. Leningr. sel. khoz. Inst. 100:155-160.
5. HORWITZ, W. 1960. Official methods of analysis of the Association of Official Agricultural Chemists. A.O.A.C. 832 p.
6. KAPOOR, I. J., & R. N. TANDON. 1970. Post-infection changes in sugar contents of tomato fruits caused by Drechslera australiense. Indian Phytopathol. 23:133-135.
7. MARCHAL, E. 1942. Elements de chimie vegetale. Masson et Cie., Editeurs. 844 p.
8. MC COMBS, C. L., & N. N. WINSTEAD. 1964. Changes in sugars and amino acids of cucumber fruits infected with Pythium aphanidermatum. Phytopathology 54:233-234.
9. OGATA, K., & T. MURATA. 1958. Studies on the storage of onions. (8) On the functional disorder of onion bulbs. J. Hort. Ass. Japan 27:111-115.
10. SAMISH, Z., & A. COHEN. 1949. Composition of oranges in Israel. Agr. Res. Sta. Rehovot, Israel.
11. SRIVASTAVA, M. P., & R. N. TANDON. 1966. Free amino acid spectrum of healthy and infected Moshambi fruit. Naturwissenschaften 53:508-509.
12. STROBEL, G. A., & T. KOSUGE. 1964. Metabolism of organic acids during rot of grape berries by Diplodia viticola. Phytopathology 54:242-243.
13. RAJZMAN, ANNA, & MINA SCHIFFMANN-NADEL. 1961. Changes on the amount and composition of lemon juice at storage. Prelim. Rep. No. 343. Nat. Univ. Inst. Agr., Rehovot [in Hebrew].