J. Agric. Sci. Mansoura Univ., 32 (5): 3733 - 3744, 2007

BIOCHEMICAL CHANGES IN RESISTANT AND SUSCEPTIBLE PEACH ROOTSTOCKS AFTEREFFECT OF THE ROOT-KNOT NEMATODE, *Meloidogyne incognita*

Farahat,A.A.*;H.Hendy;H.I.El-Naggar*and Ahlam,M.El-Ghonaimy****
*** Fac. of Agric., Cairo University**
**** Desert Research Center**

ABSTRACT

Changes in ascorbic acid, total indoles, tannins, total carbohydrates and amino acids in resistant (Nemaguard, Nemared and Okinawa) and susceptible (Meetghamr) peach rootstocks grown in two types of soil and infected with the root-knot nematode, *M. incognita* were assessed. Roots and leaves of the resistant rootstocks grown in sandy soil had higher contents of ascorbic acid than the susceptible, Meetghamr. Leaves of all rootstocks had higher amounts of indoles than roots, seedlings grown in clay than those grown in sandy soil. Resistant rootstocks had percentages of tannins in their roots higher than the susceptible one and vice versa in leaves. Nematode infection resulted in increasing ascorbic acid, indoles and tannins contents and the highest percentages of increase was, in most cases in the susceptible rootstock, Meetghamr. No distinct variations could be observed between the susceptible and the resistant rootstocks in their contents of carbohydrates. In contrast, nematode infection decreased carbohydrate contents and the highest reduction was in Meetghamr.

Fifteen amino acids were present in roots and leaves of different peach rootstocks. Roots of the susceptible rootstock either healthy or infected grown in sandy or in clay soil had higher values of amino acids than the resistant ones especially aspartic, serine, glutamic, valine and arginine. Nematode infection slightly decreased the amounts of amino acids except few cases and rates of amino acids reduction varied according to rootstock. Such biochemical changes are, in part, involved in the resistance of peach rootstocks.

Keywords: Peach, *M. incognita*, Chemical changes, Resistance.

INTRODUCTION

The use of resistant rootstocks is the perfectible choice in nematode management in perennial crops. It is considered the staddle of the first defense line against nematode infection. In peach, there are many rootstocks known to be nematode-resistant cultivated world wide and substantially diminish nematode populations in infested farms. Chemical components of a plant host are among the numerous factors responsible for resisting nematode infections, some of these chemicals are altered by nematode infection in different ways in the resistant and susceptible hosts. Such biochemical alterations in the susceptible and resistant plants were studied by many research workers in trials to understand the nature of resistance and susceptibility of plant hosts. Most researches advocated that nematodes alter the contents of certain chemicals in plant tissues during their development.

Total protein increased proportionally with nematode infection in galled roots of okra, eggplant and grapes while carbohydrates and lipids decreased (Baus and Sukul, 1983 and Kesba, 2003). Nematode infection also increased amino acids with different rates in the susceptible or resistant cultivars of tobacco (Hanounik *et al*., 1975). *M. incognita* increased some amino acids and decreased some others in grape (Kesba, 2005).

Nematode infection decreased total carbohydrates and reduced sugars (Epestein, 1972 and Baus and Sukul, 1983), however, Kheir and Abadir (1982) reported an increase in potato roots infected with *M. incognita*. Also *M. incognita* did not affect concentrations of reducing sugars but non reducing sugars increased in susceptible and decreased in moderately resistant variety of grape (Melakeberhan *et al*., 1990).

Much lower amounts of ascorbic acid were determined in tissues of susceptible cultivars than in resistant ones (Zacheo *et al.*, 1977 and Mathur *et al*., 1991)

The present study is conducted to find out the variations between resistant peach rootstocks and the susceptible local one in their contents of certain chemicals when they were grown in either sandy or in clay soil. As well, the alteration in such chemicals resulted from the infection with the root-knot nematode, *M. incognita* to find out to what extent these chemicals are involved in resistance.

MATERIALS AND METHODS

One year old nematode-free seedlings of three resistant peach rootstocks, Nemaguard, Nemared and Okinawa as well as the local susceptible, Meetghamr were grown singly in 25 cm diameter clay pots filled with sterilized sandy and/or clay soil with an average weight of 5-6 kg. Four pots of each rootstock were inoculated with 5000 J2 / pot of the root-knot nematode, *M. incognita* while another four were left without inoculation to serve as a check. Nematode inoculum was introduced to the seedlings by pouring the nematode water suspension in 5 holes around the root system, immediately covered with the same wetted soil. After three months of inoculation, plants were harvested and data on plant growth and nematode counts were recorded. The total carbohydrate content (according to Smith *et al*., 1964), ascorbic acid (according to A.O.A.C., 1970) , total indoles (according to Singh, 1982) and tannins (according to A.O.A.C., 1970) were determined in leaves and roots of each rootstock in both types of soil. As well, amino acids were determined by amino acid analyzer " Eppendor FLC 3000". The peak area and percentage of each amino acid were calculated by computer software AXXIOM CHROMATOGRAPHY.

RESULTS AND DISCUSSION

Data presented in Table (1) enunciate the differences in the contents of roots and leaves of susceptible and resistant peach rootstocks of ascorbic acid, total indoles, total carbohydrates and tannins when they were grown in sandy or clay soil as well as the alterations in such chemicals aftereffect of the root-knot nematode, *M. incognita*.

It is perspicuous from the table that leaves had higher contents of ascorbic acids than roots in all rootstocks in both types of soil. In sandy soil, healthy roots of Okinawa (highly resistant) had the highest value of ascorbic acid, while, Meetghamr (susceptible) had the lowest value. Infection with the root-knot nematode resulted in increasing ascorbic acid contents and the highest percentage of increase (220%) was in roots of Meetghamr followed by Nemared and Nemaguard (106,104%, respectively). The highest value of ascorbic acid in leaves was also recorded in Okinawa followed by Meetghamr. Nematode infection as well, upraised leaves contents of ascorbic acid and the highest percentage of increase was also observed in leaves of the susceptible rootstock, Meetghamr.

Table (1): Biochemical variations between susceptible and resistant peach rootstock, healty and infected with the root-knot nematode , *M. incognita*, grown in two soil types.

Rootstock	Soil Type							
	Sand				Clay			
	Root		leaves		Root		Leaves	
	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected
Ascorbic acid								
Meetghamr	1.2*	3.84	5.30	7.32	3.01	4.16	3.23	5.92
Nemaguard	1.8	3.68	5.00	6.08	2.10	4.16	4.23	6.88
Nemared	2.1	4.32	4.91	6.56	1.94	3.68	5.86	7.32
Okinawa	2.6	4.16	7.53	9.76	1.90	3.84	3.71	5.92
Total indoles								
Meetghamr	13.40	21.97	15.20	95.18	12.30	19.04	15.50	102.51
Nemaguard	14.56	24.89	17.80	95.18	14.10	23.43	24.43	124.47
Nemared	11.80	14.64	24.76	124.47	13.10	21.97	14.97	93.72
Okinawa	10.83	14.64	17.23	114.22	12.98	21.97	17.85	73.22
Tannins								
Meetghamr	0.301	0.504	0.083	0.286	0.213	0.336	0.226	0.336
Nemaguard	0.521	0.588	0.203	0.235	0.900	0.974	0.264	0.386
Nemared	0.247	0.269	0.070	0.094	0.498	0.521	0.113	0.118
Okinawa	0.600	0.655	0.614	0.638	0.610	0.672	0.115	0.118
Total carbohydrates								
Meetghamr	27.90	25.05	27.40	25.10	37.20	36.60	32.50	29.66
Nemaguard	24.00	22.41	33.80	31.30	29.80	28.02	29.60	28.02
Nemared	27.20	25.71	33.90	32.30	30.90	29.66	29.70	28.02
Okinawa	29.90	28.05	25.00	23.37	31.50	29.66	31.20	29.66

*** mg / 100 g fresh weight**

In clay soil, the opposite was observed whereas the highest value of ascorbic acid was recorded in Meetghamr roots and the lowest in those of Okinawa. Likewise, *M. incognita* increased roots content of ascorbic acid. The highest percentage of increase was noticed in Okinawa and the lowest in Meetghamr roots. Leaves of Nemared had the highest value of ascorbic acid while Meetghamr had the lowest ones. The highest augmentation in ascorbic acid resulted from nematode infection was recorded in leaves of Meetghamr followed by Nemared and Okinawa (Fig. 1).

The present results are in congruence with those of Zacheo *et al.* (1977) whom said that amounts of ascorbic acid in plant tissues of susceptible cultivars were much lower than that in resistant ones, and those of Arrigoni *et al.*(1979) when they reported that ascorbic acid depletion in plants has attenuated resistance in tissue to the root-knot nematode infections.

Fig. (1) : % Increase in ascorbic acid, indoles, tannins and % reduction in total carbohydrates contents of roots and leaves of peach rootstocks as influenced by *M. incognita* infection in two types of soil.

They hypothesized that plants utilized ascorbic acid for the synthesis of mitochondorial hydroxyproline proteins which control the development of cyanide resistant respiration. They also stated that the amount of ascorbic acid in susceptible plants was unaltered by nematode attacks, but in resistant plants ascorbic acid synthesis always was stimulated. Also Mathur *et al.* (1991) found higher concentrations of ascorbic acid in galled tissues than in normal ones. These findings emphasized that ascorbic acid play an important role in nematode infectivity and reproduction in plant tissues and in helping infected plants to overcome nematode infection.

Concerning total indoles, sensible variations could be observed between the susceptible rootstock and those resist nematode infection. Likewise ascorbic acid, leaves of all rootstocks had higher amounts of indoles than roots. As well, rootstocks grown in clay soil have had in their roots and leaves higher amounts of indoles than those grown in sandy soil, in which, roots of Nemaguard had the highest content followed by Meetghamr. Withal, nematode infection gave rise to roots content of total indoles and the highest percentage of increase was recorded in Nemaguard roots followed by Meetghamr. In leaves, Nemared had the highest values of indoles, followed by the other two resistant rootstocks, however, Meetghamr had the lowest value.

Spanking increase in leaves content of indoles resulted from nematode infection in sandy soil reaching 562 % in Okinawa and 526% in Meetghamr (Fig.1). Similar trend was noticed in case of clay soil, yet the highest percentage of increase was recorded with the susceptible rootstock.

In peach tissues, indole 3 acetic acid and indole 3 acetic acid oxidase are responsible, in part for peach fruit growth and maturation (Valpuesta *et al.,* 1989), while indole buteric acid is responsible for the vegetative growth of cuttings (Bora and Das, 1998) and increased root length (Rufato and Kersten, 2000). Indole acetic acid is involved in the formation of the feeding sites of root-knot nematode (Zukerman and Rohde, 1981). They said that tissues of the susceptible plants had higher concentrations of indole acetic acid than that in resistant ones. Accordingly exogenous applications of indole acetic acid resulted in increasing its concentration in root tissues of infected plants which enhanced the development of invaded larvae to reach maturation faster than the untreated (Al-Rehiayni *et al*., 2001). From this point of view, the amount present of indole acetic acid in plant tissue is not involved in resistance, it is just responsible for delaying or enhancing the formation of giant cells. Yet, in case of the lack of even low concentrations of indole acetic acid may provoke the formation of feeding sites of the invaded stages resulting in their death. The success of the invaded larvae in forming giant cells in tissues of resistant rootstocks asserted this point of view.

Massive variations could be observed between the susceptible and resistant rootstocks in their contents of tannins. Resistant rootstocks had percentages of tannins in their roots considerably higher than those in Meetghamr except for Nemared in sandy soil. It could be also observed that, contradictory to ascorbic acid and total indoles, roots content of tannins preponderated that in leaves 2-3 times and more.

In sandy soil, Okinawa and Nemaguard roots had the highest values of tannins content, while, Meetghamr and Nemared had lower values. Nematode infection raised roots content of tannins and the highest percentage of increase was achieved in Meetghamr roots (67%) vs 8.9% in Nemared roots. In leaves, Okinawa had amounts of tannins equal to those observed in its roots, nematode infection increased tannins in leaves by 3.9%. Leaves of Meetghamr had low amounts of tannins (one fourth of that in roots) and nematode infection increased it by 275% (Fig. 1).

In clay soil, roots of Meetghamr had the lowest content of tannins as compared to those in resistant rootstocks which had almost 2 – more than 4 folds of that present in roots of Meetghamr. Nematode infection also increased tannins by 57, 8, 5 and 10% in roots of Meetghamr, Nemaguard, Nemared and Okinawa, respectively. In contrast, leaves content of tannins in the resistant rootstocks are lower than those in the susceptible one. The highest percentage of increase in leaves content of tannins due to nematode infection was observed in case of Meetghamr.

Tannins are accumulated in vegetable buds of peach during spring then disappeared in summer, new tannins-containing cells were formed during autumn and winter (Eraud *et al*.,2000). Tannins and momeric phenol concentrations were lower in low quality cultivars than in white or yellow-fleshed, commercial quality ones (Senter and Callahan, 1990). Condensed tannin contents inhibited beta-cyanoalanine synthase which resulted in the production of hydrogen cyanide in the roots which reduced plant growth (Mizutani *et al*., 1988) . Tannins condensed in the epidermal cells of peach are responsible for necrotic lesions of bracts (McAvoy *et al.,* 1998). According to these findings, tannins may be play an important role in resistance of resistant rootstocks which contain in their roots higher amounts of tannins comparing to the susceptible rootstock. Such role may be the formation of necrotic lesions around the invaded larvae in root tissue resulting in hindering the formation of giant cells

No distinct variations could be observed between resistant and susceptible rootstocks in their contents of total carbohydrates. It could be generally said that leaves content of total carbohydrates are remarkably higher than roots except some few cases (Table, 1). Nematode infection resulted in reducing total carbohydrates in roots and leaves. Percentages of reduction, in the majority of cases, are somewhat higher in sandy than in clay soil (Fig. 1). Likewise, the highest reduction in both roots and leaves in either sandy or in clay soil was observed in the susceptible rootstock, Meetghamr.

These findings comported with those of Nyczepir *et al*. (1987) when they stated that *Criconemella xenoplax* reduced sugar content in roots and/or stem tissue of Nemaguard peach seedlings. Accordingly, continuous exposure of peach to nematode invasion may affect fruit crop quantitatively and qualitatively. Kheir and Abadir (1982) found that tubers and shoots of potato infected with *M. incognita* contained less amounts of total sugar. Other investigators (Massoud, 1971; Epstein, 1972; Massoud, 1980, Shohla, 1980 and Melakeberhan, *et al*., 1990) reported that nematode infection either increased or did not alter the content of carbohydrates of infected plants.

Amino acids were determined in roots and leaves of healthy and infected susceptible and resistant rootstocks grown in sandy and clay soils, and data are presented in Tables 2 – 5. It is obvious from the tables that roots and leaves of different rootstocks had 15 amino acids namely, aspartic, therionine, serine, glutamic, glycine, alanine, valine, methionine, isolucine, lucine, tyrosine, phenylalanine, histidine, lysine and arginine.The highest value of amino acids content in roots of Meetghamr grown in both types of soil were aspartic, glutamic, and lucine while tyrosine had the lowest value and methionine was not detected (Tables 2,4).In Nemaguard roots; aspartic,lucine and glutamic had the highest values; phenylalanine had the lowest and methionine and tyrosine were not detected. In roots of Nemared and Okinawa, like in Meetghamr, aspartic, glutamic and lucine had the highest values, tyrosine had the lowest but methionine was detected in roots of Nemared grown in clay soil.

In leaves, more or less similar results were obtained. It could be generally said that roots of the susceptible rootstock either healthy or infected , grown in sandy or clay soil had higher values of amino acids than those in the resistant rootstocks especially aspartic, serine, glutamic, valine and arginine. Nematode infection resulted in almost all cases (few exceptions) in a slight reductions in amino acids. The highest rates of amino acids reduction were in tyrosine in Meetghamr (13.06%), Nemared (11.63%) and Okinawa (12.59%), however the highest reduction in Nemaguard was in glycine (10.36%). It is worthy to observe that nematode infection increased the amino acids; valine in roots of Nemared grown in sandy soil by 83.96% and lucine in Meetghamr leaves by 38.81% and by 85.94% and 56.27%, in leaves of Nemaguard grown in sandy and clay soil, respectively as well as phenylalanine (56.27%) in leaves of Nemaguard grown in clay soil (Tables 3,5).

It could be also noticed that percentages of amino acids reductions due to nematode infection are generally higher in roots than in leaves of different rootstocks irrespective of the type of soil in which it was grown.

In conclusion, there were conspicuous differences in the amounts of amino acids presented in the susceptible rootstock and the resistant ones. Such differences are more pronounced in sandy than in clay soil.

In literature, antipodal results have been reported on quantitative and qualitative root contents of amino acids in infected and non infected plants. Amino acids significantly increased in roots of susceptible plants and unchanged in roots of resistant hosts (Doney *et al*., 1970 and Lewis& McClure, 1975). However Singh and Choudhury (1974) found no differences in amino acid contents in resistant and susceptible tomato roots. Hanounik *et al.* (1975) recorded an increase with different rates in either susceptible or resistant tobacco, however, Tayal and Agrawal (1982) recorded high levels of amino acid reduction in tissues of eggplant.

Natural differences in the amount of amino acids between different rootstocks, may be or not, involved in the variable response of these rootstocks to nematode infection.

T2-3

T4-5

The slight reduction in amino acid contents which was higher in roots than in leaves and in susceptible than in resistant rootstocks, resulted presumably from the utilization by nematodes during the development and the formation of the feeding sites. Only few exceptions in which amino acids were increased as a result of nematode infection. Kesba (2005) reported that *M. incognita* resulted in increasing some amino acids and decreasing some others in roots of Thompson seedless grape seedlings.

REFERENCES

Al-Rehiayani, S.M.; Belal, M.M. and Farahat, A.A. (2001). Influence of reproduction of the root-knot nematode, *Meloidogyne javanica* infecting indole acetic acid, Gibberellic acid and ascorbic acid on the infectivity and eggplant, *Solanum melongena*, Egypt. J. Of Agric.Nematol. 5(1): 25-36.

A.O.A.C.(1970). Official method analysis, Association of Official Analytical Chemists, Washington Dc., 11th ed., p. 240.

Arrigoni, O.; Zacheo, G.; Arrigoni-Liso, R.; Beleve-Zacheo, T. And Lamberti, F. (1979). Relationship between ascorbic acid and resistance in tomato plants to *Meloidogyne incognita*. Phytopathol., 69: 570-581.

Baus, S.P. and Sukul, N.C. (1983). Effect of root-knot nematode on the different stages of *Hibiscus esculentus*. Indian J. of Nematol. 13 (1) 66-70.

Bora, A. and Das, R.P. (1998). Role of indole butyric acid (IBA) on vegetable growth of rooted cuttings of some minor fruits of Assam. J. of Agric Sci. Soc. of North-East India, 11 (2): 197-201.

Doney, D.L.; Fife, J.M. and Whitney, E.D. (1970). The effect of sugarbeet nematode*, Heterodera schachtii* on free amino acids in resistant and susceptible *Beta* species. Phytopathol. And Plant Protection. 60:1727-1729.

Epstein, E. (1972). Biochemical changes in terminal root galls caused by an ectoparasitic nematode, *Longidorus africanus* phenols, carbohydrates and cytokinins. J. of Nematol., 4:246-250.

Eraud, C.; Loiseau, M. and Tort, M. (2000). Development of tannin-containing cells in the vegetative buds of peach trees during an annual growth cyde. Act-Botanica Gallica., 47 (2): 199-207.

Hanounik, S.B.; Osborne, W.W. and Pirie, W.R. (1975).Influence of *Meloidogyne incognita* on the content of amino acid, nicotine in tobacco grown under gnotobiotic conditions. J. of Nematol., 7: 322-336.

Kesba, H.H. (2003).Integrated nematode management on grape grown in sandiness soil. Ph.D. Thesis , Fac. Agric., Cairo Univ., pp. 189.

Kesba, H.H. (2005). Effectiveness of amino acid foliar application on *Meloidogyne incognita* and biochemical alterations in grape roots. Bull. Fac. Agric., Cairo Univ., 56 (3): 617-630.

Kheir, A.M. and Abadir, S.K.(1982). Effect of *Meloidogyne incognita* infection on carbohydrate contents of potato plants. Res. Bull., Fac. of Agric. Zagazig Univ., 489:1-12.

Lewis, S.A. and McClure, M.A. (1975). Free amino acids in root of infected cotton seedlings resistant and susceptible to *Meloidogyne incognita.* J. of Nematol. 7: 10-14.

Massoud, S.I. (1971). Studies on plant parasitic nematodes attacking the leguminasae. M.Sc. Thesis Fac. Agric., Alexandria Univ.147 pp.

Massoud, S.I. (1980). Nematode problems in leguminasae crops with special emphasis on Egyptian clover. Ph.D. Thesis, Fac. Agric., Cairo Univ., pp 147.

Mathur, A., Singh, S and Kaut, U. (1991). Ascorbic acid metabolism and growth in nematode induced root gall and normal tissue cultures of tomato. Indian J. of Plant Physiology, 34 (1): 9-13.

McAvoy, R.J.; Binle, B.B. and Evans, M.R. (1998). Localized accumulation of condensed tannins associated with poisettia bract necrosis. J.of the American Soc. For Horticulture Sci., 123-125.

Melakeberhan, H.; Ferris, H. and Dias, J.M. (1990). Physiological response of resistant and susceptible cultivars to *Meloidogyne incognita*. J. of Nematol., 22 (2): 224-230.

Mizutani, F.; Hirota, R. and Kadoya, K. (1988). Inhibition of beta-cyanoalanine synthase activity by growth inhibitors from peach roots. J. of Japanese Soc. For Horticulture Sci., 57(1): 22 – 27.

Nyczepir, A.P.; Reilly, C.C. and Okie, W.R. (1987). Effect of initial population of *Criconemella xenoplax* on reducing sugars, free amino acids and survival of peach seedling over time. J.of Nematol., 14 (3): 296-303.

Rufato, L. and Kersten, E. (2000). Rooting of cuttings of peach (*Prunus persica*L.) Batsch c.v Eseralda and Revista. Brasileira de Fruticultura, 22(2): 191 – 194.

Senter, S.D. and Callahan,A. (1990). Variability in the quantities of condensed tannins and other major phenols in peach fruit during maturation. Alon Hantea 47 (11): 514-515.

Shohla,G.S. (1980). Host-parasite relationship of certain plant parasitic nematodes infecting field crops with special refrence to sugar beet and kenaf. Ph.D. Thesis, Fac. Agric., Cairo Univ., pp. 97.

Singh, A. (1982). Practical Plant Physiology, 2nd Ed. Kalyani Publishers New Delhi-Ludhiana, New Delhi 110002.

Singh, B. and Chaudhury, B. (1974). Screening tomato cultivars for resistance to *Meloidogyne* species. Pest Arcticles and News Summaries. 20 (3): 319-322.

Smith, D.; Pastsen, G.M. and Roguse, C.A. (1964). Extraction of total available carbohydrates from grass and legumes tissue. Plant physiology, 39: 960-962.

Tayal, M.S. and Agrawal, M.L. (1982). Biochemical alterations in galls induced by *Meloidogyne incognita* : some hydrolyzing enzymes and related chemical metabolites.Indian J. of Nematol. 12: 379-382.

Valpuesta, C.; Quesada,M.A.; Sanchez-Raldan, C.; Tigier,H.A.; Heredia, A. and Bukocac,M.J. (1989). Changes in indole-3-acetic acid, indole-3-acetic acid oxidase and proxidase isoenzymes in the seeds of developing peach fruits. J. of Plant Growth Regulation, 8 (4):255-261.

Zacheo, G, Lamberti, F.; Arrigoni-Liso, R. and Arrigoni, O. (1977).Mitochondorial protein-hydroxyproline content of susceptible and resistant tomatoes infected by *Meloidogyne incognita*. Nematologica Mediterranean, 34:471.

Zukerman, B.M. and Rohde, R.A. (1981). Plant Parasitic Nematodes. Vol III . Academic Press Inc. Fifth Avenue, New York, 10003.

التغيرات الكيماوية بين أصناف الخوخ المقاومة والصنف البلدي الحساس نتيجة الإصابة بنيماتودا تعقد الجذور في نوعين من التربة

أحمد عبد السلام فرحات* , حسن حامد هندي , حسن إبراهيم النجار* و أحلام محمد الغنيمي****

*** كلية الزراعة – جامعة القاهرة**

**** مركز بحوث الصحراء**

تم في هذا البحث دراسة محتوى جذور وأوراق الأصناف المقاومة (نيمجارد و نيمارد و أوكيناوا) والصنف الحساس (ميت غمر) من حمض الأسكوربيك والإندولات والتانينات والكربوهيدرات الكلية والأحماض الأمينية ومدى تأثير نيماتودا تعقد الجذور على هذا المحتوى وذلك في نوعين من التربة (الرملية والطينية) وأوضحت النتائج ما يلي:

كانت جذور وأوراق الأصناف المقاومة النامية في الأراضي الرملية تحتوي علي كميات من حمض الأسكوربيك أكبر من جذور وأوراق الصنف الحساس (واتعكس في الأراضي الطينية) وقد أدت الإصابة بالنيماتودا إلى زيادة محتوى كل الأصناف غير أن نسبة الزيادة كانت اكبر في الصنف الحساس .

كان محتوى الأوراق من الإندولات أكبر من مجتوى الجذور في كل الأصناف ، محتوى النباتات التي نمت في التربة الطينية عن التي نمت في التربة الرملية وفي أوراق النباتات المقاومة عن أوراق الصنف الحساس. كما أدت الإصابة بالنيماتودا إلى زيادة نسبة الإندولات وكانت معدلات الزيادة في الأوراق أكبر منها في الجذور .

كان هناك إختلافات كبيرة بين الأصناف المقاومة من ناحية والصنف الحساس من ناحية أخرى في محتواها من التانينات حيث كانت نسبة التانينات في جذور الأصناف المقاومة أعلى منها في الصنف الحساس والعكس بالعكس بالنسبة للأوراق في بعض الأصناف وعلي العموم كانت نسبة التانينات في الجذور اكبر منها في الأوراق بعدل ٢-٣ أضعاف أو أكبر . أيضا أدت الإصابة بالنيماتودا إلى زيادة نسبة التانينات في الجذور والأوراق لكل الأصناف ولكن كانت نسبة الزيادة أكبر في الصنف الحساس .

لم يكن هناك فروقاً واضحة بين الأصناف المقاومة والصنف الحساس في محتواها من الكربوهيدرات الكلية ، وكان محتوى الأوراق أكبر من محتوى الجذور وأدت الإصابة بالنيماتودا إلى انخفاض محتوى الجذور والأوراق من الكربوهيدرات وكان أعلى معدل انخفاض في الصنف الحساس .

احتوت جذور وأوراق الخوخ على ١٥ حمض أميني وكانت كميتها في جذور الصنف الحساس السليمة والمصابة النامية في التربة الرملية أو الطينية أكبر من تلك التي في جذور الأصناف المقاومة وخاصة حمض الأسبارتيك، السيرين، الجلوتاميك والفالين والأرجينين وأدت الإصابة بالنيماتودا إلى انخفاض طفيف في محتوى النباتات من الأحماض الأمينية .

تدل النتائج على أنه ربما يكون لهذه الكيماويات دوراً (مع عوامل أخرى كثيرة) في مقاومة الخوخ للإصابة بنيماتودا تعقد الجذور.

Table (2) : Amino acids content of roots of peach rootstocks grown in sandy soil as influenced by *M. incognita* infection.

Amino acid µ/ml	Peach rootstocks											
	Meetghamr			Nemaguard			Nemared			Okinawa		
	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.
Aspartic	360.816	355.178	1.56	204.357	199.201	2.52	335.921	330.609	1.58	317.65	313.465	1.32
Therionine	165.353	158.635	4.06	70.723	63.0271	10.88	164.231	160.017	2.57	135.28	131.465	2.46
Serine	202.350	195.503	3.38	83.967	77.7693	3.38	186.785	181.627	2.76	154.82	149.565	3.40
Glutamic	309.192	303.691	1.78	138.937	133.395	3.99	288.975	283.794	1.79	245.35	239.987	2.19
Glycine	150.416	143.614	4.52	64.384	57.711	10.36	154.983	150.981	2.58	134.95	128.014	5.15
Alanine	156.314	150.13	3.96	73.673	66.761	9.38	173.234	168.579	2.69	140.35	135.963	3.13
Valine	215.879	209.178	3.10	100.975	94.8793	6.04	114.947	211.459	+83.96	179.85	175.383	2.49
Methionine	-	-	-	-	-	-	-	-	-	-	-	-
Isolucine	150.756	144.075	4.43	71.862	65.6428	8.65	150.753	147.177	2.37	126.87	121.681	4.09
Lucine	207.785	201.267	3.14	98.940	92.049	6.97	208.859	204.321	2.17	180.29	174.992	2.94
Tyrosine	54.974	47.7954	13.06	-	-	-	55.549	49.0525	11.63	43.587	38.0981	12.59
Phenylanine	121.852	115.385	5.31	49.976	44.8789	10.250	118.124	113.612	3.82	93.742	87.4433	6.72
Histidine	142.438	136.1	4.45	96.764	90.1726	6.81	132.348	126.436	4.47	110.86	105.568	4.78
Lysine	162.517	156.105	3.94	145.834	138.398	5.10	173.983	169.608	2.52	143.68	148.364	+3.26
Arginine	120.529	115.215	4.41	61.947	55.39	10.59	99.678	93.5746	6.12	98.834	94.4843	4.40

*** % red = % Reduction**

Table (3) : Amino acids content of leaves of peach rootstocks grown in sandy soil as influenced by *M. incognita* infection.

Amino acid µ/ml	Peach rootstocks											
	Meetghamr			Nemaguard			Nemared			Okinawa		
	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.
Aspartic	332.43	330.304	0.64	417.62	415.424	0.53	440.436	437.393	0.69	400	397.924	0.52
Therionine	113.95	110.495	3.3	140.5	136.005	3.20	184.5	180.078	2.40	63.427	59.7794	5.75
Serine	129.75	126.467	2.53	149.57	146.757	1.88	186.975	182.414	2.44	126.96	124.629	1.84
Glutamic	224.5	220.496	1.78	282.2	279.101	1.10	330.846	327.284	1.08	203.17	199.731	1.69
Glycine	125.62	122.261	2.67	155.21	151.422	2.44	190.486	187.511	1.56	150.69	147.069	2.40
Alanine	135.39	131.193	3.10	157.83	154.228	2.28	190.821	188.41	1.26	140.64	138.36	1.62
Valine	165.99	161.663	2.61	188.31	185.493	1.50	134.932	231.954	71.90	145.75	142.725	2.08
Methionine	-	-	-	-	-	-	-	-	-	75.725	71.277	5.87
Isolucine	120.73	118.207	2.09	136.93	134.129	2.0	187.923	185.281	1.41	35.626	32.0266	10.10
Lucine	167.44	165.404	1.22	110.92	206.249	+85.94	265.924	262.301	1.36	100.28	96.0823	4.19
Tyrosine	55.867	52.7826	5.52	68.719	65.337	4.92	106.974	104.789	2.04	50.654	46.654	4.87
Phenylanine	105.18	102,711	2.35	135.74	132.377	2.48	160.015	157.103	1.82	81.864	78.8264	3.71
Histidine	116.71	114.17	2.18	134.27	130.762	2.61	172.216	170.121	1.22	295.94	292.409	1.19
Lysine	161.86	159.848	1.24	185.48	182.248	1.74	236.379	234.322	0.87	135.94	131.313	3.40
Arginine	82.478	79.244	3.92	149.54	155.065	3.70	165.821	162.228	2.17	56.537	52.2533	7.58

% red. = % Reduction

Table (4) : Amino acids content of roots of peach rootstocks grown in clay soil as influenced *by M. incognita* infection.

Amino acid µ/ml	Peach rootstocks											
	Meetghamr			Nemaguard			Nemared			Okinawa		
	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.
Aspartic	496.745	490	1.23	383.985	377.852	1.60	450.213	443.402	1.51	342.78	335.997	1.98'
Therionine	180.476	173.121	4.08	109.753	102.573	6.54	241.510	233.01	3.52	103.29	96.9692	6.12
Serine	195.120	189.125	3.07	120.412	113.451	5.78	255.105	247.994	2.87	115.78	108.834	6.00
Glutamic	336.242	329.349	2.05	113.986	208.296	+82.74	415.600	409.432	1.48	190.95	184.372	3.45
Glycine	174.911	167.895	4.01	108.951	101.83	6.54	217.984	210.116	3.61	105.94	97.4902	7.98
Alanine	195.109	188.242	1.98	16.964	11.012	35.08	304.262	208.314	31.54	130.21	124.02	4.76
Valine	232.568	226.45	2.63	147.967	142.382	3.77	300.427	294.824	1.87	142.24	135.432	4.79
Methionine	-	-	-	-	-	-	36.9753	23.25	23.25	-	-	-
Isolucine	185.682	178.768	3.72	105.153	98.8765	5.97	241.958	235.14	2.82	94.659	88.162	6.86
Lucine	254.015	248.051	2.35	149.254	142.895	4.26	315.752	309.075	2.12	129.39	122.913	5.01
Tyrosine	52.9687	46.8667	11.51	-	-	-	91.534	84.3513	7.85	-	-	-
Phenylanine	130.984	124.617	4.86	74.9875	67.9533	9.38	210.263	203.642	3.15	67.586	59.9205	11.34
Histidine	173.537	166.044	4.32	113.684	97.3166	14.40	254.267	247.122	2.81	86.934	81.9213	5.77
Lysine	219.637	211.766	3.58	144.916	137.116	5.41	365.581	358.424	1.96	117.87	111.983	5.00
Arginine	208.314	203.421	2.35	122.526	114.065	6.91	85.985	78.0292	9.25	134.26	127.626	4.95

% red. = % Reduction

Table (5) : Amino acids content of leaves of peach rootstocks grown in clay soil as influenced by *M. incognita* infection.

Amino acid µ/ml	Peach rootstocks											
	Meetghamr			Nemaguard			Nemared			Okinawa		
	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.	Healthy	Infected	% red.
Aspartic	493.2	448.2	9.16	456.13	^51.127	1.09	504.861	500.77	0.81	420.78	416.478	1.02
Therionine	221.36	218.737	1.18	233.85	229.528	1.85	155.959	153.994	1.26	193.85	188.258	2.89
Serine	230.62	226.015	1.99	226.98	223.829	1.39	170.693	168.533	1.27	187.57	183.435	2.21
Glutamic	435.13	432.003	0.72	415.95	412.774	0.76	330.851	329.012	0.50	345.75	340.157	1.62
Glycine	227.99	225.325	1.16	234.11	229.119	2.13	160.65	156.562	2.55	200.74	196.474	2.13
Alanine	204.95	200.085	2.37	215.33	211.776	1.65	165.65	163.423	1.34	192.76	188.475	2.22
Valine	283.59	279.055	1.60	275.98	273.3	0.97	216.251	211.245	2.3	241.33	238.895	1.01
Methionine	80.978	74.9327	7.47	31.859	29.5443	7.27	-	-	-	29.957	26.9638	9.99
Isolucine	276.36	271.221	1.86	243.45	238.54	2.02	166.954	163.591	2.01	205.95	201.449	2.19
Lucine	245.71	341.057	+38.81	332.82	328.185	1.39	239.815	235.442	1.82	330.31	328.213	0.64
Tyrosine	160.96	159.552	0.88	142.95	138.744	2.94	90.984	87.525	3.79	109.8	106.777	2.75
Phenylanine	234.57	230.057	1.92	166.81	261.181	+56.27	140.891	138.861	1.44	176.11]	171.101	2.84
Histidine	243.96	240.33	1.49	226.51	223.154	1.48	153.461	149.144	2.81	162.47	158.604	2.38
Lysine	291.21	287.356	1.32	309.86	305.586	1.38	215.987	213.977	0.93	245.82	242.188	1.48
Arginine	-	-	-	-	-	-	-	-	-	-	-	-

%red. = %Reduction

83