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Replant Problem in Fruit Crops: Issues and Possibilities of its Control in Pome and Stone Fruits

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ABSTRACT

Replant disease has an enormous effect on the productivity of pome (apples, pears) and stone fruits (peaches, plums), especially when new orchards are planted on previously cultivated soils. The disease is prevalent in various regions worldwide, including Himachal Pradesh, India, where it impacts orchard profitability significantly. Both biotic (e.g., soil-borne diseases, nematodes) and abiotic variables (e.g., soil compaction, nutrient imbalances) contribute to the problem, resulting in decreased growth and production. Traditional chemical management practices, such as soil fumigation, are becoming more limited due to environmental concerns. As a result, sustainable solutions such as biological control with beneficial bacteria, compost additives, and the use of biofumigant crops are being investigated. Integrated management solutions, which combine biological and organic treatments, offer promise for reducing replant disease while improving soil quality. More study is required to optimize these tactics, improve microbial inoculant formulations, and create replant-tolerant rootstocks for long-term orchard sustainability.

Keywords: *Replant disease, fruit crop, rootstock, temperate fruits, orchard sustainability.*

Introduction

A major agricultural issue that impacts fruit crop productivity globally is the replant problem, particularly concerning pome (apples, pear) and stone fruits (cherries, peaches, and mangos). This problem arises when new trees are planted in soils that were previously used for the same kind of orchard, which leads to stunted development, lower yield, and low productivity all around. Particularly in areas where replanting is required because the old orchards have outlived their economic usefulness, the problem makes new plantations unfeasible and threatens the sustainability of orchards. The apple replant issue has been prevalent in Himachal Pradesh, India, particularly in the districts of Shimla and Kullu. In Kullu, rates have been reported to range from 25-70% [11]. The ongoing nature of this problem emphasizes the necessity for better understanding and management. A primary factor contributing to the replant problem is the age of the orchard. In many regions, orchards established in the 1950s and 1960s have either declined due to pests and diseases or have outlived their productive period, making replanting necessary. When these older sites are replanted without proper management, newly planted trees often exhibit stunted growth and other symptoms associated with replant problems [89]. This has raised concerns among orchardists and researchers alike, prompting the exploration of strategies to mitigate the effects.Setting "replant disease" apart from "replant problem" is crucial.

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While "replant problem" includes both biotic and abiotic elements, such as soil compaction, nutrient imbalances, and poor soil structure, "replant disease" refers particularly to the inhibition of tree growth brought on by soil-borne pathogens, such as fungi, bacteria, and nematodes. Replant illness is typically regarded as a part of the larger replant issue [89].

Problems with replanting are common worldwide and impact different fruit-growing regions. For example, 61% of orchards in Poland have replant disease signs [88], whereas 85% of replant orchards in Italy have replant disease symptoms [66]. The issue was present in every soil utilized for apple replanting in Tasmania [32]. According to research by Campbell [15], the problem is most common in Australian soils, particularly in neutral to slightly acidic and light basaltic soils.The replant issue can last for decades and is frequently exclusive to particular plant species or genera. For instance, even with extended time between plantings, apple and rose plants are severely harmed when cultivated in the same soil repeatedly. According to Klaus, this location-specific, immovable problem can last for 20–30 years. Cross-reactions have been noted, even though they are typically believed to be species-specific; cherry trees have demonstrated poor growth when grown in soils that were previously used for apples [54].The replant problem has a complicated etiology that includes both biotic and abiotic causes. Nematodes such as Pratylenchus penetrans attack roots biologically, resulting in symptoms like stunting, discoloration, and the production of "witches-brooms" [39]. Additionally implicated are soil-borne pathogens, which include oomycetes and fungi including Rhizoctonia solani, Phytophthora, Cylindrocarpon, and Pythium [56, 55, 46]. These elements work together to produce an environment that is unfavorable to replant growth, hence more research and the creation of efficient management techniques are required.

One major problem impacting apple orchards around the world is apple replant disease. Methyl bromide and other soil fumigation techniques are expensive, detrimental to farmers, and deplete the ozone layer. An eco-friendly and safer option may be to use genetically resistant apple rootstocks. The economic impact of replant disease is examined by [32], who emphasizes how it affects profitability, particularly in high-density apple plantings. It is imperative that orchard management handle the disease as its yield losses might render otherwise lucrative operations unfeasible.

Replant problems are classified into two types

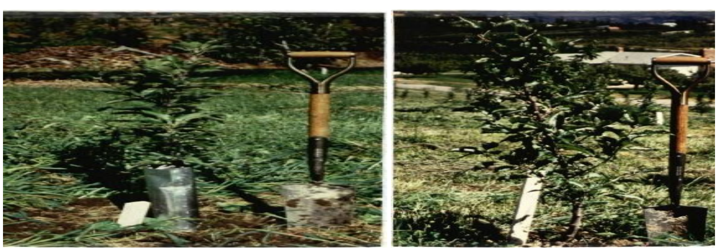
1. Specific: Occurs when the same or related species (e.g., apple after apple) are replanted, involving both biotic and abiotic factors.

2. Non-specific: This happens when different species (e.g., apple after cherry) are planted, primarily due to abiotic factors. Stunted growth, small, light-green leaves, decaying roots, and general tree health are some of the symptoms, which cause yields to be lower and fruit production to be delayed. Apples and peaches are most affected by ARD, but grapes, citrus, cherries, almonds, pears, plums, and apricots are less affected. Selective use of pesticides and altered cultural practices are examples of control methods.

Symptoms of replant problem

a) Apple *b) Peach*

Fig. 1 Symptoms of replant problem on apple (a) and peach (b)



Stunted Shoot Growth Healthy tree

Shortened Internodes Reduced root system

Causes of Replant Problem

Replant problems in fruit crops are caused by biotic and abiotic factors

1. Biotic Causes: Fungi, bacteria, nematodes, actinomycetes, and the interactions between nematodes and fungi are the primary biotic factors. Microorganisms are found in the fine roots that remain in the soil after old plants are removed. These microbes cause illnesses and growth inhibition by either directly harming young plant roots or competing with them for resources.

A) Fungi: Rhizoctonia, Cylindrocarpon, Pythium, Phytophthora, Thielaviopsis, Fusarium, and Penicillium are the main fungi linked to replant disease. These fungi impede the growth and development of a variety of fruit crops.

Table 1. Fungi reported as cause of replant disease in fruit crops

Fungi	Host	Reference
Rhizoctonia, Phytophthora, Pythium	apple	Caruso *et al.* (1989)
Alternaria, Cylindrocarpon, Fusarium, Rhizoctonia and *Verticillium*	apple	Kowalik (1999)
Fusarium equiseti, F. oxysporum, Rhizoctonia sp.	peach, cherry	Fliegel *et al.* (1963)
*Phytophthora citrophthora, Pythium aphanidermatum*and *Fusarium solani*	citrus	Hassan *et al.* (1989)
Penicillium, Fusarium, Gliocladium spp. and Roesleria hypogaea	grapes	Deal *et al.* (1972)
Thielaviopsis basicola	cherry	Pepin *et al.* (1975)
Dematophoranecatrix, Fusarium oxysporum, Phytophthora spp. *and Pythium* spp.	apple	Kumar *et al.*(1998)

Catska and Taube [18] reported the presence of phytotoxic micromycetes(*Penicillium* sp. and *Alternaria* sp.) in ARD soil at Rheinland, Germany (Table 2).

Table 2. Effect of *Glomus etunicatum*alone and together with *Agrobacterium radiobacter* population of *Azospirillum* sp. and phytotoxic micromycetes (CFU) in rhizoplane of grafted apple trees growing in ARD soil. The percentages are given concerning untreated control (virgin soil).

Soil	CFU of microorganisms (%)	
	*Azospirillum*sp. (BCA)	Phytotoxic micromycetes (*Penicillium* sp. and *Alternaria* sp.)
Virgin soil	100.0	100.0
ARD soil	35.33	454.54
ARD + *G. etunicatum*	41.69	295.45
ARD + *G. etunicatum*+ *A. radiobacter*	96.46	245.45

2. Bacteria

Replant illnesses in a variety of fruit crops are caused by bacteria. In British Columbia, certain strains of Bacillus subtilis have been connected to stunted apple seedling growth [91]. In Czechoslovakia, apple replant disease is linked to Pseudomonas putida [19]. Amygdalin from peach roots can be used by Agrobacterium tumefaciens strains CN-X4 and CN-X17 and Pseudomonas sp. strain CN-X9 to produce poisonous hydrocyanic acid (HCN) in the soil [105]. Citrus replant issues are also linked to fluorescent pseudomonads.

3. Nematodes

Many fruit crops suffer from replant diseases, which are largely caused by nematodes. Apples are impacted by Xiphinema and Pratylenchus species [60], while citrus replant issues are associated with Tylenchulussemipenetrans [76]. Meloidogyne javanica affects stone fruits, while other nematodes such as Xiphinema, Criconemoides, Meloidogyne, and Pratylenchus species are detected in grapevines [1].

Table 3. Nematode counts in virgin (non-peach), sick (replant problem)and fresh (healthy peach) soil types

Land Type	*Heliocorhynchus* sp.	*Meloidogyne* sp.	*Pratylenchus* sp.	*Tylenchorhynchus*sp.	*Ziphenema* sp.	Total
Virgin	0	0	0	0	110	110
Sick	0	20	100	220	10	350
Fresh	30	0	10	60	0	100
Total	**30**	**20**	**110**	**280**	**120**	

4. Actinomycetes
Actinomycetes have been shown to infect replant soils in a some nations, including Germany [67]. They cause rootlet die-off in woody plants like apples by harming the cortical cells of the rootlets [87]. In the USA, England, and Czechoslovakia, actinomycetes have also been connected to ARD. Actinomycetes were found in Sorbus and pear plants cultivated in ARD-affected soil, but not in Prunus and Rosa plants, according to research by [103]. This suggests that some crops are not suited as antecedents for apple planting.

5. Fungus and Nematode Interaction
It has been discovered that interactions between nematodes like Thielaviopsis basicola and Pratylenchus penetrans and fungus can lead to replant disease in a variety of fruit crops [37]. According to histopathological investigations, apple roots in replant soils contain nematodes and fungal hyphae such as Rhizoctonia, Phytophthora, and Pythium [17]. According to reports, Pratylenchus and Pythium have a major role in ARD [58].

II. Abiotic Causes
Abiotic factors such as phytotoxins, nutrient imbalances, soil structure, and moisture also contribute to replant problems.

1. Phytotoxins: Allelochemicals in particular have a major impact on the growth of seedlings and plants, resulting in soil sickness in lucerne, apple, peach, citrus and asparagus [2]. These allelochemicals are released by decomposed crop residues at the same time that new crops germinate [21]. The main causes of replant issues in peaches are harmful substances such as benzaldehyde and hydrocyanic acid (HCN) [34].

Key sources of HCN in peach orchards include:

1. Wounded roots releasing ten times more HCN than intact roots.

2. Degradation of amygdalin in peach roots by soil microorganisms, leads to HCN formation [106].

The replant problem is also associated with substances such as prunasin and condensed tannins [62]. According to research, peach roots in soil release more HCN than those in virgin soil [34]. Peach root growth is inhibited by condensed tannins, especially in anaerobic environments [63].

Table 4. Evolution of HCN from oven dried root of peach and soil suspensions in water (0.25 g dry roots + 5 g soil + 40 ml water, reaction time 3 h). (5 replicates).

Additive to root suspension	HCN evolution (µg/g soil)
None (without soil)	1.7
Virgin soil	1.8
Soil from pots with young peach plant	4.1

2. Physical Factors
Physical soil conditions such low pH, compaction, inadequate irrigation, nutrient deficits (e.g., N, P, K, and zinc), and residues from pesticides containing arsenic might cause problems with replanting . Additional considerations include the toxicity of heavy metals like manganese and aluminium [40] and low temperatures, which make people more vulnerable to cold injury [54]. Waterlogged conditions and hard pan at the subsurface level can inhibit root growth and encourage the growth of pathogens.

Management of Replant Problem
Auto-toxicity, microbes, and poor management of previous crops are some of the causes of replant problems. Since the causes are difficult to identify and vary by area, prevention is best. The exact reason determines the control measures.

1. Cultural Practices
Modifying cultural practices can help manage replant problems:

- Dig pits away from old planting sites.
- Remove and destroy old roots.
- Break up hard pan and avoid water logging.

a) Applicationof Fertilizers and Manures
Compost and other organic additions improve soil structure, nutrient availability, and moisture retention while reducing disease through microbial activity [22]. In pot studies, compost has improved the growth of apple seedlings [81]. Beneficial bacteria that fight infections are encouraged by the use of N and P fertilisers [93]. Additional supplements, such as monoammonium phosphate and biohumus, have also demonstrated efficacy in promoting seedling growth and mitigating the consequences of ARD [88].

Effect of Treatments on Apple Trees in ARP Soil
Research has shown various treatments improve shoot growth and trunk cross-sectional area (TCA) of young apple trees planted in ARP soil.

- **Monoammonium Phosphate (MAP)**: Wojcik and Klamkowski found that pre-plant application of MAP at 1 g L⁻¹ on coarse-textured soils enhances tree precocity, particularly in soils low in phosphorus.

- **Compost and Fertilizers**: Schoor et al., 2009 and Engel et al., 2001 reported significant growth improvements in seedlings from ARD soil when slow-release fertilizers, compost, and mulch were applied.

- **Fungicides and Organic Materials**: Szczygiel and Zepp found that biohumus (10-20% dosage) and monoammonium phosphate (2 g L⁻¹) were particularly effective, alongside the fungicides Aliette and Captan, in enhancing growth parameters of apple seedlings.

b) Intercropping
In replanted soil, apple seedling development can be greatly increased by intercropping with herbaceous crops [97]. By generating volatile gases, crops including mustard, radish, and cabbage aid in the management of soil-borne diseases [31]. Additionally, spreading red fescue (Festuca rubra) and red top (Agrostis alba) showed modest antagonistic activity, whereas

marigolds (Tagetes patula, cv. Harmony) significantly reduced populations of Pratylenchus penetrans and Pythium species, according to research by [26]. On the other hand, canola boosted these pathogen populations. Nematode numbers may be decreased before planting by thorough raking and removing grass clumps, amongother effective ground preparation techniques.

c) Steam Sterilization

It has been demonstrated that steam sterilising apple replant disease (ARD) soil up to 70°C promotes the healthy growth of replanted trees [68]. Despite its effectiveness, this approach is not economical in India. When strawberries were subjected to 70°C for 10 days or 55°C for 20 days, Wang [100] discovered that soil sterilisation greatly decreased bacteria and fungi while increasing root activity and respiratory metabolism.

d) Mulches and Other Practices

Soil solarization with polyethylene mulch, alone or combined with soil fumigation, effectively controls soil-borne pathogens. In orchard soils, plastic mulches have been found as effective as methyl bromide and formalin against ARD [43]. Additional practices include deep ploughing and using grass mulch between rows [28].

2. Chemical Control

The most dependable technique for guaranteeing healthy orchard performance following replanting has been soil sterilisation using fumigants because it can be difficult to pinpoint the precise causes of replant disease. Formalin, 1,3-dichloropropane, methyl bromide, and chloropicrin are examples of fumigants that are often used. Chloropicrin has emerged as a viable substitute for methyl bromide, which has been the main option since 1950 but is currently prohibited in several nations, including India [14].

However, chemical fumigation can contribute to environmental pollution and damage important soil microflora, such as arbuscular mycorrhizal fungi [57]. In comparison to virgin soil, both Dazomet and Metham-sodium produced comparable growth and yield outcomes in apple trees during studies [66].

A 5% formalin treatment considerably boosted the height and girth of grafted apple trees, according to Kumar et al. (1998)[48]. The Chaubattia Princess and Early Shanburry trees showed the largest increases inheight, 207.34% and 286.34%, respectively.

According to Eayre [25], replant diseases were successfully managed by fumigation using methyl bromide or methyl iodide at 392 to 448 kg/ha. Additionally, a double fumigation method that combined methyl bromide and chloropicrin produced greater outcomes than single treatments[35].

Biological Control

Replant issues are successfully managed by soil fumigation and chemical treatments, but they upset the natural equilibrium between pathogens and helpful microbes. A more sustainable approach is biological control. According to Utkhede and Smith, 1991b [94], apple trees afflicted with apple replant disease (ARD) grew more when the soil was soaked with Bacillus subtilis. Agrobacterium radiobacter has also been shown to enhance apple plant growth in ARD soil [18].

Another biological control strategy is mycoparasitism, in which some fungi parasitize harmful fungus. Trichoderma species are well-known mycoparasites that help control infections by producing hydrolytic enzymes including chitinase and β-1,3-glucanase [36].

Additionally, arbuscular mycorrhizal fungi (AMF) are essential root symbionts that increase nutrient and water intake, boost tree vigor,and reduce susceptibility to abiotic stresses [84]. Bharat and Bhardwaj, 2001 [10] found that local isolates of *Glomus spp.* Effectively reduced disease severity and increased growth parameters in apple seedlings by enhancing VAM root colonization.

Table 8. Effect of VAM fungi on severity of white root rot of apple

VAM	Disease severity (%)	VAM root colonization (%)
Glomus mosseae	37.5 (37.75)	26.0 (30.92)
G. fasciculatum	38.0 (38.03)	27.0 (31.05)
Acaulospora laevis	32.5 (34.74)	37.0 (37.46)
Gigasporagilmorei	56.5 (48.74)	21.0 (27.55)
Glomus spp. (local isolate)	27.5 (31.61)	40.0 (39.0)
Control	100.0 (90.0)	-
CD (0.05)	1.54	1.13

Figures in parentheses are arc sine transformed values

Table 9. Effect of VAM x Dematophora Necatrix Interaction on growth characteristics of apple seedlings

VAM	Increase in seedling height (cm)	Increase in seedling dia. (cm)	Increase in root length (cm)	Leaf area (cm²)
Glomus mosseae	8.34	0.62	3.60	17.20
G. fasciculatum	1.072	0.34	3.20	15.80
Acaulospora laevis	12.10	0.80	4.28	17.0
Gigasporagilmorei	4.56	0.30	2.18	14.0
Glomus spp. (local isolate)	13.28	0.90	6.04	18.60
Control	3.28	0.12	1.06	13.60
CD (0.05)	1.79	0.09	0.63	0.64

Host Resistance

It takes time to develop replant-tolerant rootstocks for fruit trees, and by the time seedlings reach maturity, resistance has frequently been lost. According to Ryan, 1975 [79], M12 rootstock should only be used in cases of root disease; heavier soils treated with chloropicrin and lighter soils are better suited for MM 115 and M793. Gisela 6, Cab 6, Colt, and Gisela 5 were found by Reginato to be relatively resistant to issues related to cherry replanting. Some fruit trees can be replanted using new rootstocks such as 'Replantac' [70].

According to Giovannini, hybrids such as GF 677 showed vigour and productivity in peach orchards, however the peach rootstocks PS A% and PS B2 were extremely susceptible to replant disease, leading to notable mortality rates.

Singh and Dhiman [83] discovered that replant issues in peach trees were associated with the prevalence of crown gall and root-knot nematodes. They suggested adding virgin soil to lessen these impacts. Rootstocks CG 6210 and G 30 were shown by Leinfelder and Merwin (2006) to be efficient in raising trunk cross-sectional area and yield.

In their evaluation of 65 rootstocks, Auvil [6] discovered that G.41 and G.11 lacked the vigour of G.935, CG.4214, and CG.4814, which fared well in non-fumigated treatments. According to studies [4], rootstocks G.30 and CG.6210 were comparatively resistant to apple replant disease.Orazem [65] identified Adesoto, Tetra, and Penta as the most promising peach rootstocks for replant conditions. Wang [100] found that *Malus hupehensis* exhibited the best tolerance among the five rootstocks tested, showing minimal decreases in photosynthesis and chlorophyll content under replant conditions. Additionally, new interspecific hybrid Prunus rootstocks were developed for calcareous and replant soils, with Barrier and Cadaman performing well in terms of tree vigor and productivity [3].

Some new promising developed rootstocks in Peach and plum for the Replant problem

Rootstock	Genetic origin	Breeding Institution
PEACH		
INRA GF-677	*P. amygdalusx P. persica*	INRA (France)
Felinem (GN-22)	*P. amygdalusx P. persica*	CITA-DGA (Spain)
Garnem (GN-15))	*P. amygdalusx P. persica*	CITA-DGA (Spain)
Monegro®(GN-9	*P. amygdalusx P. persica*	CITA-DGA (Spain)
Cadaman®Avimag	*P. persica* x *P. davidiana*	IFGO (Hungary) and INRA (France)
Barrier	*P. davidianax P. persica*	CNR (Italy)
PLUM		
Adesoto	*Prunus insititia*	Spain
Ishtara-Ferciana	(*P. cerasifera × P. salicina) x (P. cerasifera × P. persica*)	France
Junior-Ferdor	*P. insititia × P. domestica*	France
Mr.S.2/5	Open pollination of *P. cerasifera*	Italy
Penta	Open pollination of 'Imperial Epineuse' (*P. domestica*)	Italy

Some tolerant and susceptible rootstocks of Apple in replanting problem

Tolerant rootstocks	Reference
G.30	Isutsa and Merwin, 2000. Rumberger, 2004. Michelli, 2006. Laurent, 2010
CG210	Isutsa and Merwin, 2000. Rumberger, 2004. Michelli, 2006.Laurent, 2010
Merton I.793	Soni, 2011
CG 5935	Robinson, 2004
CG4202	Robinson, 2004
Susceptible rootstocks	
G-65	Laurent, 2010
M26	Laurent, 2010, Rumberger,2006.Mazzola,2003
M-7	Rumberger, 2004
CG16	Rumberger, 2004
MM 106	Mazzola, 2003
MM 111	Mazzola, 2003

Some tolerant and susceptible rootstocks of Pear in replant problem

Tolerant rootstocks	Reference
Pyrus communis	Webster et al., 2000
Pyrus centifolia	Webster et al., 2000
Provence Quince (BA 29-C)	Webster et al., 2000
OH × F97	Wertheim, 1997
OH × F69	Wertheim, 1997
Susceptible rootstocks	
Quince seedlings or clones	Michelesi, 1995
Pyrus calleryana	Jacob, 1998
Pyro-2	Jacob, 1998

Some tolerant and susceptible rootstocks of Peach, Plum and Almond in replant problem

Tolerant rootstocks	Reference
Nemaguard	Loreti, 1994.
Guardian	Loreti, 1997.
Rubira	Reighard, 2000.
Viking	Mc Kenry *et al*, 2004.
Krymsk 5, Krymsk1	Seavert and Long, 2007.
Shalil, Yunan, Okinawa, Higama, Penta, Myran, Julior.	Reighard, 2000.
Tetra	Wescott *et al*, 1994.
Succeptible rootstocks	
Lovell, Bailey	Moreno, 2004.
Halford	Moreno, 2004.
Ishtara	Wescott *et al*, 1994.
Adara (*Prunus cerasifera*)	Reighard, 2000.

Some tolerant and susceptible rootstocks of cherry in replant problem

Tolerant rootstocks	Reference
Gisella 6	Lang *et al*, 1998
Gisella 12	Lang *et al*, 1998
Mazzard	Webster *et al*. 2000
Colt	Long, 1995
Maxma 14	Long and Kaiser, 2010.
Succeptible rootstocks	
Gisella 5	Lang *et al*, 1998
Weiroot 158	Long and Kaiser, 2010.
Gisella 7	Lang *et al*, 1998
Mahaleb	Spotts *et al*, 2010.

Integrated Management

It might be difficult to tackle the replant issue with a single management strategy because the precise causes can differ by place. Therefore, replant difficulties can be effectively addressed with an integrated management approach. Apple trees at the Summerland location responded to formalin treatment, whereas those at the Kelowna site benefited from monoammonium phosphate (MAP), according to experiments done by [92]. At the Summerland site, the best outcomes were obtained by combining bacterial treatments, such as Enterobacter aerogenes strain B8, with MAP. In comparison to formalin alone, the bacterial strains BACT-1, EBW-4, B-10, and B8 improved tree growth at Kelowna. Lime use also lessened the impact of the replant issue, particularly when paired with bacterial strains and fumigation.

[95] Suggested that MAP alone might suffice to alleviate the replant issue, while incorporating B. subtilis strains or Enterobacter aerogenes could further enhance tree growth. Bhardwaj and Sharma [11] found that the most effective treatment in Kullu, India, involved using old apple orchard topsoil, additional phosphorus, and a formalin drench to promote shoot growth in affected orchards.

Table 11. Growth improvement in apple trees under different treatments

Sr. No.	Treatment	Increase in shoot growth (%)
1	Old apple orchard top soil	-
2	Sr.No.1+Additional P	29.21
3	Sr.No.1+ Formalin drench	64.03
4	Sr.No.1+ Additional P + Formalin drench	84.57
5	Old apple orchard sub soil	24.44
6	Plum orchard soil	39.41
7	Pear orchard soil	31.50
8	Persimmon orchard soil	53.59

Raj and Sharma, [72] evaluated four isolates of VAM and two of Azotobacter chrococcum on Golden Delicious seeds and seedlings against Dematophoranecatrix (apple root rot). They found that the AZUHF1 isolate of A. chrococcum and AMUHF1 (Glomus fasiculatum) were the most effective treatments, enhancing shoot and root lengths under both solarized and sterilized (formalin) conditions, as well as in the control group.

Table 11. Effect of seed inoculation of apple with Azotobacter chrococcumand root inoculation with vesicular-arbuscular mycorrhiza on shoot and root length in different soil treatments during 2004

Treatment[a]	Shoot length (cm)			Root length (cm)		
	Solarized	Sterilized	Control	Solarized	Sterilized	Control
AMUHF1	91.7	84.5	68.1	9.0	8.4	6.1
AMUHF2	89.0	83.0	67.9	8.7	8.1	6.1
AMUHF3	90.0	82.6	66.1	8.9	8.1	6.2
AMUHF4	90.5	83.2	67.9	8.9	8.2	6.1
AZUHF1	86.7	81.5	65.2	8.5	8.0	5.9
AZUHF1 x AMUHF1	120.1	108.0	70.3	9.9	9.0	6.9
AZUHF1 x AMUHF2	116.8	104.6	68.4	9.4	8.8	6.6
AZUHF1 x AMUHF3	114.3	103.2	67.2	9.2	8.7	6.4
AZUHF1 x AMUHF4	113.2	103.6	67.1	9.2	8.6	6.4
AZUHF2	85.8	80.2	65.2	8.8	8.0	6.0
AZUHF2 x AMUHF1	118.5	110.8	69.3	9.7	9.0	6.8
AZUHF2 x AMUHF2	117.1	107.5	69.1	9.5	8.9	6.7
AZUHF2 x AMUHF3	115.4	103.8	68.7	9.5	8.9	6.8
AZUHF2 x AMUHF4	116.9	102.9	68.9	9.6	9.0	6.7
Control	83.47	75.63	56.3	8.1	7.2	5.4

AZUHF1 and AZUHF2 are isolates of *Azotobacter chrococcum*, while AMUHF1, AMUHF2, AMUHF3, and AMUHF4 correspond to *Glomus fasiculatum*, *G. macrocarpum*, *G. mosseae*, and *Gigaspora sp.*, respectively.

Utkhede and Smith [97] found that using biological agents, including Enterobacter agglomerans strain B8, Bacillus subtilis strain EBW-4, and *Glomus intraradices*, enhanced the growth and fruit yield of Gala apple trees on M.9 rootstock in replant disease-prone soils.

Kandula [45] noted that Trichoderma treatments significantly improved arbuscular mycorrhizal (AM) colonization in soil affected by soilborne apple replant disease (SARD), while in fumigated soils, AM colonization remained low.

Kandula [44] observed that commercial Trichoderma formulations combined with NPK supplements enhanced growth in treated plants. Angelika [4] reported that soil fumigants could effectively control apple replant disease when combined with biological and cultural practices, while Biro [12] found that the efficiency of plant growth-promoting rhizobacteria (PGPR) depended on the inoculation frequency in both steamed and "sick" soils.

FutureThrusts: Future strategies should prioritize rapid and accurate diagnosis of both biotic and abiotic factors contributing to replant issues. Emphasis should be placed on eco-friendly management through biological control agents, which enhance soil fertility and reduce the reliance on chemical inputs. Research should focus on developing resistant rootstocks suitable for diverse soils and climates, as well as those that can withstand changing environmental conditions such as drought or extreme temperatures. Additionally, the integration of precision agriculture tools, such as soil sensors and remote sensing, could enable real-time monitoring of soil health and pathogen presence, facilitating early intervention and more targeted management. Collaborative approaches between researchers, growers, and policymakers are needed to create region-specific, scalable solutions that balance productivity with environmental sustainability. Finally, long-term studies on the impact of these integrated approaches on orchard resilience, biodiversity, and soil health are needed to ensure that sustainable management practices can be maintained over multiple growing seasons.

Conclusion: Pome and stone fruit orchards provide considerable obstacles to replanting because of a variety of allelopathic agents, such as allelochemicals, microbiological species, weeds, and nutritional parameters. Root susceptibility is influenced by phytotoxins and pathogens like nematodes and root fungus. Allelopathic effects are amplified by weeds like Brachiariadecumbens and Lantana camara. Particularly vulnerable are species like Prunus cerasifera and Pyrus calleryana, as well as rootstocks including Lovell, Bailey, and Gisella 5. Solarisation and fumigation continue to be the only effective measures. More investigation into the physiological and biochemical interactions of these phytotoxins is essential given the complexity of this problem.

Key Points:

1. Replanting poses serious challenges on old orchard sites.
2. Causes include both biotic and abiotic factors.
3. Etiology is complex and poorly understood.
4. Host resistance and long-term control measures are essential.
5. An integrated management strategy utilizing resistant rootstocks and bio-control agents is recommended.

REFERENCES

1. Abdalla N, Raski D J, Lear B and Schmitt R V. 1974. Movement, persistence, and nematicidal activity of a pesticide containing 1, 3-dichloropropene in soils treated for nematode control in replant vineyards. *Plant Disease Reporter* 58: 562-566.

2. Ajsaadawi I S and RubeaaA J. 1985. Allelopathic effects of Citrus aurantiumL. 1. Vegetational patterning. J. Chem. Ecol. 11: 1515—1525.

3. Alonso J M and Espada J L. 2011. Influence of the rootstock on the agronomic performance of 'Jesca' peach under replant conditions. *Acta Horticulturae* (903): 489-493

4. Angelika R, Shengrui Y, Ian A M, Eric B, Nelson J E and Thies. 2004. Rootstock genotype and orchard replant position rather than soil fumigation or compost amendment determine tree growth and rhizosphere bacterial community composition in an apple replant soil.*Plant and Soil*. 264: 247–260.

5. Angelika S, Laurent, Ian A, Merwin, Gennaro F, Janice E. Thies and Michael G. 2010. Brown rootstock genotype succession influences apple replant disease and root-zone microbial community composition in an orchard soil. *Plant Soil.* 337: 259–272.

6. Auvil T D, Schmidt T R, Hanrahan I, Castillo F, McFerson J R and Fazio G. 2011. Evaluation of dwarfing rootstocks in Washington apple replant sites. *Acta Horticulturae.* 903: 265-271.

7. Benizri E, Piutti S, Verger S, Pages L, Vercambre G, Poessel J L and Michelot P. 2005. Replant diseases: bacterial community structure and diversity in peach rhizosphere as determined by metabolic and genetic fingerprinting. *Soil Biology and Biochemistry* 37(9): 1738-1746

8. Benson N R.1976. Retardation of apple tree growth by soil arsenic residues. *Journal of American Society of Horticulture Science* 101:251-253.

9. Bent E, Loffredo A, Yang J I, McKenry M V, Becker J O and Borneman J. 2009. Investigations into peach seedling stunting caused by a replant soil. *FEMS Microbiology Ecology* 68: 192-200.

10. Bharat N K and Bhardwaj L N. 2001. Interactions between VA-mycorrhizal fungi and *Dematophoranecatrix* and their effect on health of apple seedlings. *Indian Journal of Plant Pathology* 19: 47-51.

11. Bhardwaj S S and Sharma I M. 2004. Replant problem in apple-causes and management. In productivity of temperate fruits, Jindal K K and Gautam D R (eds), Dr. Y S Parmar University of Horticulture and Forestry, Solan, H.P., India, pp. 417-422.

12. Biro B, Magyar K, Varady G and Kecskes M. 1998.Specific replant disease reduced by pgpr rhizobacteria on apple seedlings.*Hort.*477.

13. Bothe H. 2009. Arbuscular mycorrhizal fungi and their roles in relieving abiotic stress. In: Crop plant resistance to biotic and abiotic factors(ed. Feldmann, F., Alford, D.V. &Furk, C.), pp. 489-498. Germany.

14. Browne G.2009. Replant disease of almond. United State Department of Agriculture Report.

15. Campbell J E. 2000. Replant strategies for apples. Pome Fruit Australia. April 2000 p 13.

16. Campbell R. 1989. Biological Control of Microbial Plant Pathogens. Cambridge University Press, Cambridge, pp. 112-160.

17. Caruso F L, Neubauer B F and Begin M C. 1989. A histopathological study of apple roots affected by replant disease. *Canadian Journal of Botany* 67: 742-749.

18. Catska V and Taube B H. 1994. Biological control of replant problems. *Acta Horticulturae* 363: 115-120.

19. Catska V, Vancura V, Hudska G and Prikryl Z. 1982. Rhizosphere microorganisms in relation to the apple replant problem. *Plant Soil* 69: 187-197.

20. Costante J F, Mai W F and Klein R M. 1985. Effects of rootstock and soil type on Pratylenchus penetrans populations in apple feeder roots. *Journal of the American Society for Horticultural Science* 110(1): 38-41

21. Dalal R P, Thakur Anirudh, Sidhu A S, Sangwan A K and Rattanpal H S. 2008. Replanting problem in citrus - a review. *Environment and Ecology* 26: 1279-1283.

22. De Ceuster, T J J and Hoitink, H A J. 1999. Prospects for composts and biocontrol agents as substitutes for methyl bromide in biological control of plant diseases. Compost Sci. Util. 7, 6-15.

23. Deal D R, Mai W F and Boothroyd C W A. 1972. Survey of biotic relationships in grape replant situations. *Phytopathology* 62: 503-507.

24. Dullahide S R, Stirling G R, Nikulin A and Stirling A M. 1994. The role of nematodes, fungi, bacteria, and abiotic factors in the etiology of apple replant problems in the Granite Belt of Queensland. *Aust. J. Exp.Agric.* 34:1177–82

25. Eayre C G, Sims J J, Ohr H D, Mackey B. 2000. Evaluation of methyl iodide for control of peach replant disorder. *Plant-Disease*. 84 (11): 1177-1179.

26. Edwards L, Vrain T and Utkhede R S. 1994. Effect of antagonistic plants on apple replant disease. *Acta Horticulturae* 363: 135-140.

27. Engel A, Kunz A and Blanke M. 2001. Effects of compost and wood chippings on soil nutrients and on vegetative and reproductive growth and fruit quality of apple to overcome the replant problem. [German]. *Erwerbsobstbau*. 43(6):153-160.

28. Engel G. 1988. Results of trials on apple replant problems at Klein-Atlendorf Experimental Station. *Acta Horticulturae* 233: 95-101.

29. Fliegel P, Parker K C and Mai W F. 1963. The fungus flora of non-suberized roots of poorly growing cherry trees. *Phytopathology* 53: 1368-1369.

30. Forge, T, Neilsen, G, & Neilsen, D. 2016. Organically acceptable practices to improve replant success of temperate tree-fruit crops. *Scientia Horticulturae*, *200*, 205-214.

31. Gamliel A and Stapleton J J. 1993. Characterization of different antifungal volatile compounds evolved from solarized soil amended with cabbage residues. *Phytopathology 83:*899-905.

32. Geldart H G. 1994. The impact of replant problem on the economics of high density apple plantings. *Acta Horticulturae*. 363: 11-18.

33. Giovannini D, Liverani A and Bordoni P. 1998. Final observations on the behaviour of peach rootstocks on sites with replant problems. *Rivista-di-Frutticoltura-e-di-Ortofloricoltura* 60(4): 67-74

34. Gur A and Cohen Y. 1988. Causes of soil sickness in replanted peaches: 1. The role of cyanogenesis in peach soil sickness. *Acta Horticulturae*233: 25-31.

35. Gur A, CohenY, Katan J and Barkai Z. 1991. Pre plant application of soil fumigants and solarization for treating replant diseases of peaches and apples. *Scientia Horticultural*. 45(3-4): 215-224.

36. Harman G E, Taylor A G and Stasz T E.1989. Combining strainsof *Trichoderma harzianum* and solid matrix priming to improve biological seed treatments. *Plant diseases*.73:631.

37. Harr J and Klingler J. 1976. Single and combined effect of Pratylenchus penetrans and Thielaviopsis basicola on the growth of cherry tree cuttings. *Z. Pflanzenkra Pflanzenschutz* 83: 615-619.

38. Hassan M S, El-Behadli A H and Alsaadawi I S. 1989. Citrus replant problem in Iraq. I. Possible role of soil fungi and nematodes. *Plant and Soil* 116: 151-155.

39. Hoestra H. 1994. Ecology and pathology of replant problems. *Acta Horticulturae* 363:1-10

40. Hoyt P B and Neilson G H.1985. Effect of soil pH and associated cations on growth of apple trees planted in old orchard soil. *Plant Soil* 86: 395-401.

41. Isutsa D K and Merwin I A. 2000. *Malus* germplasm varies in resistance or tolerance to apple replant disease in a mixture of New York orchard soils. *HortScience* 35: 262-268.

42. Jacobs J N and Cook N C. 2003. The effect of rootstock cultivar on the yield and fruit quality of 'Packham's Triumph Doyenne du Comice Forelle Flamingo and Rosemarie 'pears. *S Afr J Plant Soil* 20: 25 –30

43. Jensen P and Buszard D. 1988. The effect of chemical fumigants, nitrogen, plastic mulch and metalaxyl on the establishment of young apple trees in apple replant disease soil. *Canadian Journal of Plant Science* 68: 255-260.

44. Kandula D R W, Jones E E Horner I J and Stewart A. 2010.The effect of Trichoderma bio-inoculants on specific apple replant disease (SARD) symptoms in apple rootstocks in New Zealand. *Australasian Plant Pathology.* 39(4): 312-318.

45. Kandula D R W, Jones E E, Stewart A. and Horner I J. 2006.Colonisation of apple roots by *arbuscular mycorrhizae* in specific apple replant disease affected soil. *New Zealand Plant Protection*. 59:92-96.

46. Kelderer M, Manici L M, Caputo F and Thalheimer M. 2012. Planting in the ' inter-row' to overcome replant disease in apple orchards: a study on the effectiveness of the practice based on microbial indicators. *Plant Soil* 357:381-393

47. Kowalik M. 1999. Soil fungi and the replant disease in an apple orchard. *Phytopathologia Polonica* 17: 31-40.

48. Kumar R, Pandey J C and Verma B L. 1998. Chemical control of replant disease of apple. *Recent Horticulture* 4: 64-68.

49. Laurent S, Merwin A, Fazio I A, Thies G and Brown J E. 2010. Rootstock genotype succession influences apple replant disease and root-zone microbial community composition in an orchard soil. *Plant and Soil*. 337(1/2): 259-272.

50. Lazarovits G. 2001. Management of soil-borne plant pathogens with organic soil amendments: a disease control strategy salvaged from the past. *Can. J. Plant Pathol*. 23: 1-7.

51. Leinfelder M M and Merwin I A. 2006. Rootstock selection, pre plant soil treatments, and tree planting positions as factors in managing apple replant disease. *Hort Science*. 41(2): 394-401.

52. Magarey R C. 1999. Reduced productivity in long term monoculture: where are we placed? Australas. *Plant Pathol*. 28: 11-20.

53. Maherali H and Kliromonos J N. 2007. Influence of phylogeny on fungal community assembly and ecosystem functioning. *Science 316*: 1746-1748.

54. Mai W F and Abawi G S. 1978. Determining the cause and extent of apple, cherry and pear replant diseases under controlled conditions. *Phytopathol* 68:1540-1544

55. Manici L M and Caputo F. 2010. Soil fungal communities as indicators for replanting new peach orchards in intensively cultivated area. *Europ J Agron* 33:188-196

56. Manici L M, Ciavatta C, Kelderer M and Erschbaumer G. 2003. Replant problems in South Tyrol: role of fungal pathogens and microbial population in conventional and organic apple orchards. *Plant and Soil* 256:315-324

57. Mark M and Luisa M M. 2012. Apple replant disease: role of microbial ecology in cause and control. *Annual Review of Phytopathology* 50:45-65.

58. Mazzola M, Brown J, Zhao X, Izzo A D and Fazio G. 2009. Interaction of brassicaceous seed meal and apple rootstock on recovery of *Pythium* spp. and *Pratylenchus penetrans* from roots grown in replant soils. *Plant Disease* 93:51-57.

59. Mazzola, M. 2003. Elucidation of the microbial complex having a casual role in the development of apple replant disease in Washington. *Phytopathology* 88 (9), 930–938

60. Melton T A, Ries S M, Noel G R and Doll C C. 1985. The peach and apple nematodes of Illinois. *Transactions of the Illinois State Horticultural Society* 119: 78-91.

61. Merwin F A and Stiles W C. 1989. Root lesion nematodes, potassium deficiency and prior cover crops as factor in apple replant disease. *Journal of American Society of Horticulture Science* 114: 724-728.

62. Mizutani F, Hirota R and Kadoya K. 1988. Growth inhibiting substances from peach roots and their possible involvement in peach replant problems. *Acta Horticulturae* 233: 37-41.

63. Mizutani F, Itamura H, Sugiura A and Tomana T. 1979. Studies on the problem of soil sickness in peach trees. II. Condensed tannins as growth inhibitors from peach roots. *Journal of the Japanese Society for Horticultural Science* 48(3): 279-287

64. Noble R and Coventry E. 2005. Suppression of soil-borne plant diseases with composts: a review. *Biocontrol Sci. Technol*. 15: 3-20.

65. Orazem P, Stampar F and Hudina M. 2011. Comparison of ten peach rootstocks performance grafted with 'Redhaven'. *European Journal of Horticultural Science* 76(5/6): 162-169

66. Otto G and Winkler H. 1993. Soil fumigation for controlling replant problems in apple orchards. *Acta Horticulturae.* 324: 91-95.

67. Otto G and Winkler H. 1998. Influence of root pathogenic actinomycetes on the trimming of the rootlets of some species of Rosaceae with root hairs. *Acta Horticulturae* 477: 49-54.

68. Otto G. 1972. Studies on the cause of specific replant disease of fruit trees. Experiments on the transfer of specific replant disease by the roots. *Zentralbl. Bakteriol. Parasitenkd. Infektionskra. Hyg*. 127: 279-289.

69. Pepin H S, Sewell G W F and Wilson J F. 1975. Soil populations of *Thielaviopsis basicola* associated with cherry rootstocks in relation to effects of the pathogen on their growth. *Annals of Applied Biology* 79: 171-176.

70. Pinochet J. 2010. 'Replantpac' (RootpacReg. R), a plum-almond hybrid rootstock for replant situations. *HortScience* 45: 299-301.

71. Politycka B and Adamska D. 2003. Release of phenolic compounds from apple residues decomposing in soil and the influence of temperature on their degradation. *Polish J Environ Studies* 12(1):95-98

72. Raj H and Sharma S D. 2009. Integration of soil solarization and chemical sterilization with beneficial microorganisms for the control of white root rot and growth of nursery apple. *Scientia Horticulturae* 119: 126-131.

73. Reginato G, Cordova C and Mauro C. 2008. Evaluation of rootstock and management practices to avoid cherry replant disease in Chile. *Acta Horticulturae* 795: 357-361.

74. Ristaino J B and Thomas, W. 1997. Agriculture, methyl bromide, and the ozone hole-can we fill the gaps? *Plant Dis.* 81: 964-977.

75. Robinson T, Anderson L, Autio W, Barritt B, Cline J, Crassweller R, Cowgill W, Embree C, Ferree D, Garcia E, Greene G, Hampson C, Kosola K, Parker M, Perry R, Roper T and Warmund M. 2006. A multilocation comparison of Geneva 16, Geneva 41 and M.9 apple rootstocks in North America. *Compact Fruit Tree* 39:22-23.

76. Roux H F le, Ware A B, Pretorius M C and Wehner F C. 1998. Comparative efficacy of preplant fumigation and postplant chemical treatment of replant citrus trees in an orchard infested with *Tylenchulussemipenetrans*. *Plant Disease* 82: 1323-1327.

77. Rumberger A, Merwin I A and Thies J E. 2006. Microbial community development in the rhizosphere of apple trees at a replant disease site. *Soil Biology and Biochem*. 39 (7), 1645–1654.

78. Rumberger A., Yao S, Merwin I A, Nelson E B and Thies J E. 2004. Rootstock genotype and orchard replant position rather than soil fumigation or compost amendment determine tree growth and rhizosphere bacterial community composition in an apple replant soil. *Plant Soil* 264: 247-260.

79. Ryan C L J. 1975. Specific replant disease in Hawkey's Bay Part IV: Control methods including fumigation technique. *Orchardist of New Zealand* 48: 194-195.

80. Savage E F, Hayden R A and Ward W E. 1968. The effect of subsoiling on the growth and yield of peach trees. *Gr. Agric. Exp. Stn. Res. Bull*. 30.

81. Schoor L Van, DenmanS and CookN C. 2009. Characterization of apple replant disease under South African conditions and potential biological management strategies. *Scientia Horticulturae* 119: 153-162

82. Seavert C and Long L E. 2007. Financial and economic comparison between establishing a standard and high. VIII International Symposium on Canopy, Rootstocks and Environmental Physiology in Orchard Systems

83. Singh J and Dhiman J S. 2004. Peach replant problem: assessment and investigation*.* *Acta Horticulturae* 662: 419-422.

84. Smith S E and Read D J. 2008. *Mycorrhizal symbiosis.* New York: Academic press.

85. Soni Mohit, Thakur Manisha and Modgil Manju. 2011. *In vitro* multiplication of Merton I. 793–An apple rootstock suitable for replantation. *Indian Journal of Biotechnology* 10: 362-368

86. Spethmann W and Otto G. 2003. Replant problems and soil sickness. In: Roberts AV, Debener T and Gudin S (ed) *Encyclopedia of Rose Science*. Elsevier Ltd, pp 169-180

87. Szabo K, Winkler H, Petzold H and Marwitz R.1998. Evidence for the pathogenity of actinomycetes in rootlets of apple seedlings from soil conducive to specific apple replant disease. *Acta Horticulturae* 477: 55-65.

88. Szczygiel A and Zepp A L. 1998. An occurrence and importance of apple replant disease in Polish orchards. *Acta Horticulturae* 477: 99-102.

89. Thompson J A. 1959. The occurrence of areas or poor growth in a fruit tree nursery. *Report of East Malling Research Station* 1958: 80-82.

90. Townshend J L, Cline R A, Dirks V A and Marks C F. 1984. Assessment of turf grasses for the management of *Pratylenchus penetrans* and *Pratylenchusprojectus*in orchards. *Canadian Journal of Plant Science* 64: 355-360.

91. Utkhede R S and Li T S C. 1988. The role of fungi, bacteria and their interaction in apple replant disease complex in soils of British Columbia. *Acta Horticulturae* 233: 75-80.

92. Utkhede R S and Li T S C. 1989. Chemical and biological treatments for control of replant disease in British Columbia*.* *Canadian Journal of Plant Pathology* 11: 143-147.

93. Utkhede R S and Smith E M. 1991a. Effect of nitrogen and phosphorus on the growth of microorganisms associated with apple replant disease and on apple seedlings grown in soil infested with these microorganisms. *Journal of Phytopathology* 132: 1-11.

94. Utkhede R S and Smith E M. 1991b. *Phytophthora* and *Pythium* species associated with root rot of young apple trees and their control. *Soil Biology and Biochemistry* 23: 1059-1063.

95. Utkhede R S and Smith E M. 1993.Evaluation of monoammonium phosphate and bacterial strains to increase tree growth and fruit yield in apple replant problem soil. *Plant and Soil* 157(1): 115-120

96. Utkhede R S and Smith E M. 1994. Development of biological control of apple replant disease. *Acta Horticulturae* 363: 129-134.

97. Utkhede R S and Smith E M. 2000.Impact of chemical, biological and cultural treatments on the growth and yield of apple in replant-disease soil.*Australasian Plant Pathology.* 29: (2).129-136.

98. Vrain T C and Yorston J M. 1987. Plant parasitic nematodes in orchards in the Okanagan of British Columbia, Canada. *Plant Disease* 71: 85-87.

99. Wang SuSu, Dong Du-Guo and Guo LuDe. 2011. Effects of soil sterilization treatments on root respiratory metabolism and development of strawberry under the replanting conditions. *Journal of Fruit Science* 28(2): 234-239

100. Wang Y Z, Yin C M, Chen Q, Shen X, Jiang Z T and Mao Z Q. 2011. Study on the difference of adaptability to replant soil in five apple rootstock seedlings. *Acta Horticulturae Sinica*. 38 (10): 1955-1962.

101. Webster T, Tobutt K, and Evans K. 2000. Breeding and evaluation of new rootstocks of apple pear and sweet cherry. *Compact Fruit Tree* 33:100-104.

102. Wertheim S. 2002. Rootstocks for European pear: a review. *Acta Hortic* 596: 299–307.

103. Winkler H and Szabo K. 1995. Filamentous bacteria cause specific replant disease. *Gartenbaumagazin* 4(8): 34-35.

104. Wojcik P and Klamkowski K. 2008. Response of 'Jonagold' apple trees in the first three years after planting to mono-ammonium phosphate fertilizer under replant problem condition. *Journal of Plant Nutrition*. 28 (8): 1397-1411.

105. Wu R, Wang-Xing Hua, Liu-Zhi Min Liu-Zheng Ping, Hu-Hao and Ma-Huan Pu. 2009. Isolation, identification and interaction of rhizosphere microorganisms involved in peach replant diseases. *Scientia Agricultura Sinica* 42: 1631-1638.

106. Xinghua W, Zhengping L, Huanpu M and Zhimin L. 2007. Screening of amygdalin degrading microorganisms and relevant antagonistic microorganisms from peach rhizosphere soil. *Acta Horticulturae* 764: 145-149.

