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Management of the apple replant problem

Apple, as we know, is the major fruit crop in the temperate regions of the world. Apple orchards planted in late sixties in India have already completed their economic lifespan. Now a declining trend in apple growing areas and its productivity has been reported thus causing loss of quality leadership for which the area is popularly known as the valley of apple. The reasons of apple low productivity could be many but one of the most important reasons is the presence of replanting problem in old declining apple orchards and the causes are frequently attributed to the biotic and abiotic factors. In this case, it is difficult to control the problem with only one method of management; hence, integrated management can be an effective tool for solving the apple replant problem.

THE poor growth of fruit trees that occurs after replanting on a site that previously supported the same or closely related species is termed "replant problem." In apple, the replant problem is widespread and has been documented in all the major fruit-growing regions of the world. Apple replant problem is characterized by uneven growth of young trees but when severe disease pressure is encountered, a majority of trees on the site may exhibit poor growth and death of young trees may occur. Symptoms of apple replant disease include severe stunting, shortened internodes, rosette leaves, small root systems, decayed or discoloured roots, and reduced productivity. Such situations arise particularly in hill ecosystem where availability of land, and options for fruit diversification are scarce. Secondly, the cultivation of other temperate fruits in not economic compared to apple. It is highly variable by site, making it difficult to diagnose and overcome through soil fumigation, solarization, use of resistant rootstocks, use of phosphate fertilizer, biocontrol and culture practices which are all the management tools to combat replant problem. Therefore, in this article, we will discuss management strategies for the relation of old apple orchard site for survival of decline apple orchards.

Soil fumigation

Causes of the apple replant problem

The replant problem is attributed to biotic (fungal, bacteria, nematodes, actinomycetes and their interactions) and abiotic (phytotoxins, nutrients imbalance, *p*H and structure) factors and are highly variable by sites, making it difficult to diagnose and overcome. The possible causes attributed to apple replant problem are discussed here.

Fungi/actinomycetes

Fungi or actinomycetes are considered as the major causal organisms responsible for apple replant problem. *Phytophthora cactorum*, *Cylindrocarpon, Pythium* species and *Rhizoctonia solani* are the dominant causal agents of apple replant problem. The several lines of circumstantial evidence collectively indicated that poor early growth of apple might be associated with the effects of soil-borne pythiaceous fungi.

Bacteria

Bacteria alone or in combinations with fungi and nematodes may contribute towards the occurrence of apple replant problem. *Pseudomonas putida* and *Fluorescent pseudomonas* may act as growth inhibitors in apple seedlings and possibly be a causative factor in the development of replant disease.

Nematodes

Nematode present in field soil contribute to apple replant problem, induce stunting, and root discolouration symptoms. Root parasitic nematodes (*Pratylenchus penetrans*) are responsible for the replant disease. Histopathological

Replant/declining apple orchards

studies have shown the presence of nematodes and hyphae of *Rhizoctonia*, *Phytophthora* and *Pythium* in the roots of apple trees in replant soil. The interactions between soil fungi such as *Phytophthora* and *Pythium* species and *Pratylenchus penetrans* are involved in apple replant problem.

Phytotoxins

The allelochemicals enhanced superoxide radical (O_2), H_2O_2 and MDA levels and increased membrane leakage in the plant tissues. The phenolic acid including phloretin, phlorizin and amygdalin generated by old apple roots can strongly inhibit the growth of new apple seedlings under replant situations. The allelochemicals impair the physiological function of the cell directly or indirectly thus retard the plant growth and cause soil sickness in old apple orchards.

Role of rootstock and variety

The different apple rootstocks and varieties respond differently in replant sick soil and show varying degree of replant disease. It is due to the growth and vigour pattern of the scion/stock, root system, water and nutrients absorption capacity of the plants. Seedlings showed severe stunting and root discolouration when grown in steamed field soil amended with 5% (v/v) untreated field soil obtained from an orchard with a history of apple replant problem. More severe effects of replant disease were found on 'Golden Delicious' than 'Cox' on M.9 rootstock.

Soil nutrients

Apple replant problem was more frequent in light sandy soil than heavy soils; however, growth improvement with control measures was reported to be better in the light rather than heavy soils. The disease has been reported more frequent in neutral or slightly acidic soils than in more strongly acid soils. The deficiency of NPK and the excess of Mn and Al in the soil causes physiological stresses lead to replant problem.

Soil *p*H and heavy metals

The poor growth of young apple trees on replant sites has been thought to be due to arsenic toxicity. The negative correlation of seedling growth with soil arsenic concentration reported that zero growth occurs at about 450 ppm total arsenic concentration. The low soil *p*H, poor irrigation practices, arsenic spray residues, soil compaction, nutrient deficiencies, selection of an inappropriate orchard system contribute to low soil fertility and apple replant problem.

Management strategies for apple replant problem

The apple replant problem may be controlled by the application of broad-spectrum soil fumigation, resistant/tolerant rootstocks, biological, cultural practices (manures and fertilizers, intercropping, mulching and thermal treatments) and integrated management. The possible management strategies to apple replant problem are discussed here.

Soil fumigation

The apple tree can be saved from replant disease with the pre-planting soil fumigation of replant sick soil with the chloropicrin @281 ml/litre/m^2, formalin @150 ml/litre/m^2, formaldehyde @200 ml/litre/m^2, metalaxyl @0.312-0.600 mg a.i./litre/m^2 and methyl bromide @100 ml/litre/m^2 which are good management strategies for apple replant problem.

Resistant/tolerant rootstocks

Use of apple replant problem tolerant/resistant rootstocks is an emerging control strategy. Apple rootstocks are more beneficial than other amendments in controlling apple replant problem at old orchard sites. None of the apple accessions has been found completely resistant to replant disease in the test soil, however, seedling accessions of *Malus hupehensis, M. sieversii* and *M. kirghisorum* had some tolerance and some clonal rootstock accessions *viz*., Morten 793, G. 11, G. 41, G. 814, G.896, CG.65, CG.6210 and CG.30 and four other clones like *Malus baccata* 1883, *Malus xanthocarpa* Xan, *Malus spectabilis* PI 589404 and *Malus mandshurica* 364 had tolerance to apple replant problem.

Biological control

Although soil fumigation and chemicals are most adaptive mean to control replant problem but not attractive as they disturb the natural equilibrium between pathogen and antagonistic microorganisms in the soil. Some of the biological control agents show increase in tree growth of apple at the replanting site by soil drenching

Applying *Bacillus licheniformis* CK-1

with *Bacillus subtilis, Agrobacterium radiobacter, Bacillus licheniformis*, *Trichoderma viride,* strain EBW-4 of *Bacillus subtilis* and strain B8 of *Enterobacter aerogenes* to mitigate replantation problem in apple. The vesicular-arbuscular mycorrhizal fungus *Glomus mosseae* and *Glomus intraradices* used alone or in combination with *Enterobacter aerogenes* and peat significantly increased their growth in apple replant problem soil and effectively control the apple replant problem.

Cultural practices

Apple replant problem has been recognized as a soil-borne problem, the attention is needed towards the modification of cultural practices such as to dig the pit slightly away from the old one, take out old roots before replanting and destroy them, removal of hardpan at sub-soil level, and avoid waterlogging and water stress. The different cultural practices reported to control replant problem are as under:

Application of manures and fertilizers

The applications of compost, compost extracts and earthworm humus were identified as promising practical tools for managing replant disease, especially under the marginal conditions. The addition of slow-release fertilizers, compost and mulch extracts significantly increased the growth parameters and survival of apple seedlings under replant sick soils. The bio-humus amendment of 10-20% and mono-ammonium phosphate at 2 g/litre of soil can be used for effective control of apple replant problem. In such situations, mono ammonium phosphate application reduces the negative effect of replant disease and enables young roots to use phosphorus without mycorrhiza.

Intercropping

The effectiveness of antagonistic plants on the populations of *Pratylenchus penetrans* and *Pythium* species which are involved in replant disease were found to be marigold *(Tagetes patula,* cv. Harmony), creeping red fescue *(Festuca rubra),* as well as red top *(Agrostis alba),* which substantially decreased the population of *Pratylenchus penetrans* and *Pythium* species. The wheat cultivation prior to planting, modified the genetic and species composition of the fluorescent *Pseudomonas* population resident to orchard soil and substantially enhanced apple seedling growth. The *Brassica napus* seed meal-induced control of *Rhizoctonia solani* as a result of enhanced activity of resident soil microorganisms, specifically *Streptomyces* species.

Mulching

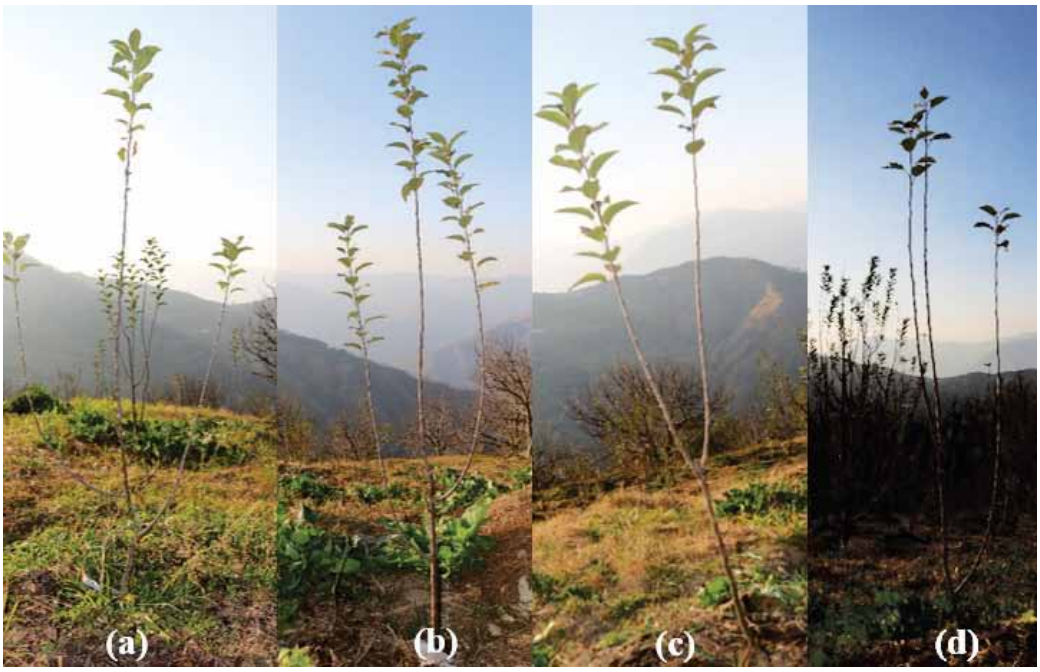
Soil solarization with polyethene mulch alone or in combination with soil fumigation with certain fumigants like formaldehyde is effective against the soil-borne pathogens. In orchard soils, the use of plastic mulches as a cultural treatment has been found to be as effective as methyl bromide, chloropicrin and formalin for controlling replant disease.

Thermal treatment

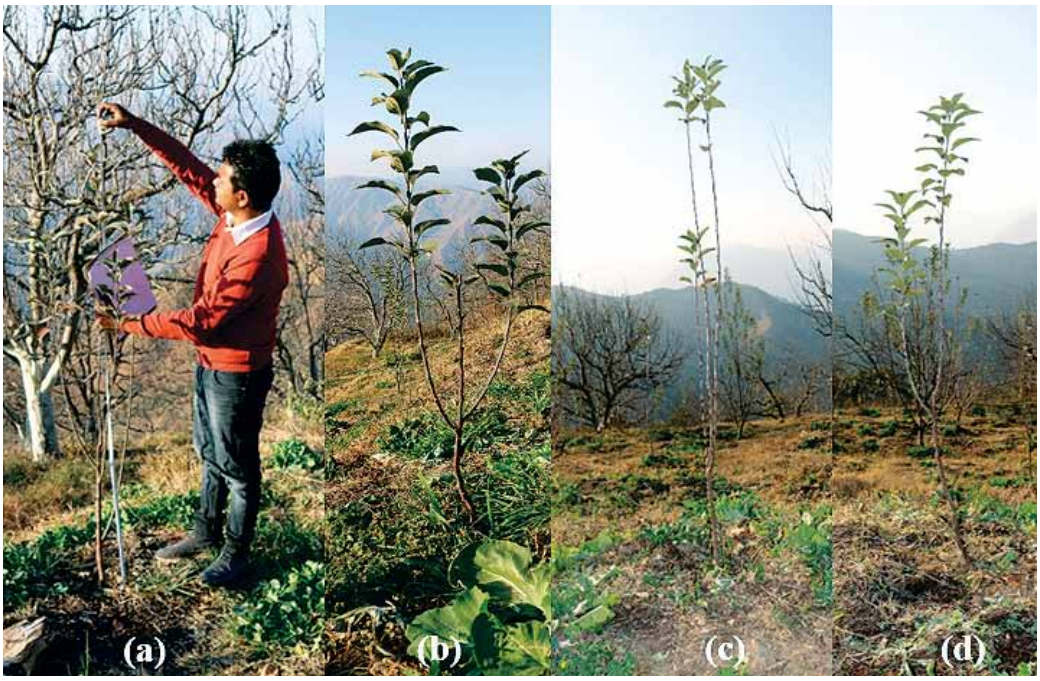
Soil steaming at 60°C or above is required for 45-60 minutes to remove growth-inhibiting agents from replanting sick soil because it reduced the activities of pathogens. The steam-heat treatments of soil reduced the effects of apple replant problem and steam for 1 minute showed 68% better growth while steaming for 2 minutes showed 120% growth improvement. The soil pasteurization enhanced the growth of apple and resulted in the change in the composition of the fungal community under replant condition.

Integrated management

The integration of cultural and biological methods for control of apple replant problem, involves use of resistant/tolerant rootstocks, biological strains in combination with mono-ammonium phosphate and lime in combination with soil fumigation for effective control of the replant problem. Avoiding replanting into the old tree rows coupled with the use of tolerant rootstocks appeared to be the best strategy for apple replant problem. The improvement in growth of apple under replant condition with commercial *Trichoderma* formulations and NPK supplement was also observed.



Growth of 'Super Chief' on *(a)* M.793, *(b)* MM.111, *(c)* M.7, *(d)* Seedling rootstocks after response to soil fumigation with Formaldehyde × *Bacillus licheniformis* CK-1 × *Trichoderma viride*



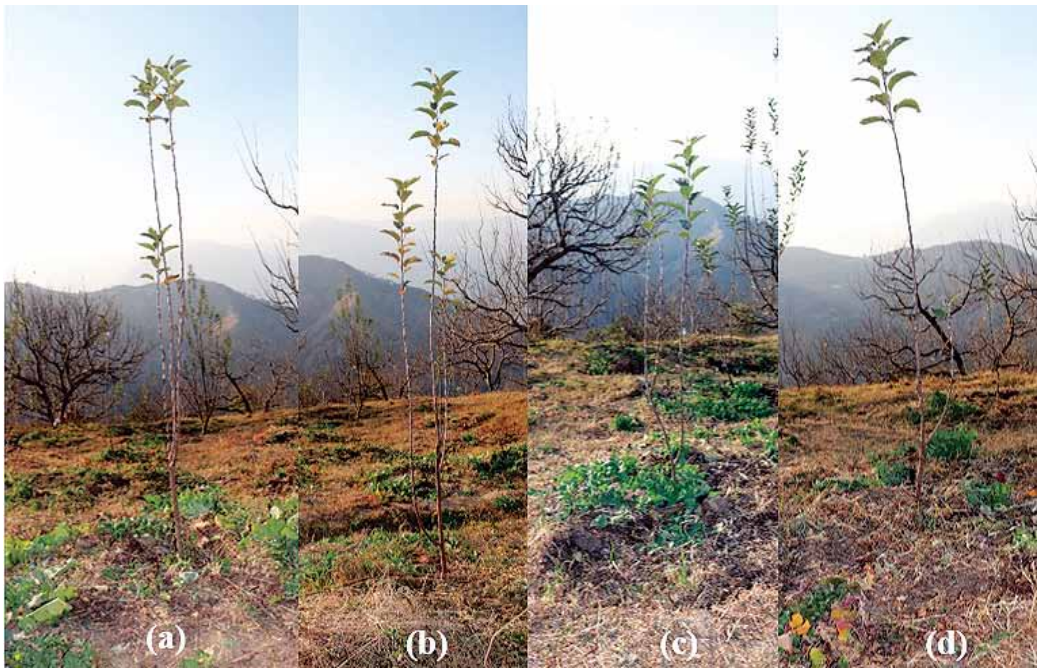
Growth of 'Super Chief' on *(a)* M.793, *(b)* MM.111, *(c)* M.7, *(d)* Seedling rootstocks after response to *Bacillus licheniformis* CK-1

Chemical

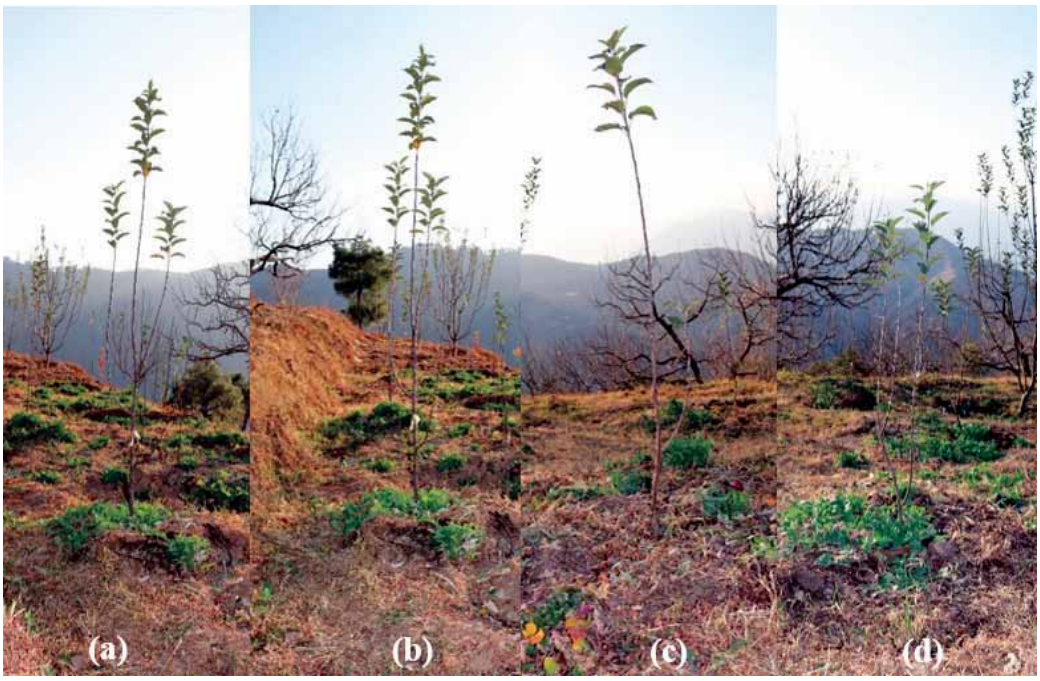
The chemical application of fungicides difenoconazole or metalaxyl enhanced the growth of apple plants in sick soil. Bavistin 0.2%, Jkstein 0.2% and Dithane Z-78 also improved the growth of apple plants in replant sick soil but were not as effective as formalin.

SUMMARY

Apple replant problem is a serious problem in the establishment of new orchards at old apple orchard sites. The disease is a complex syndrome that reduces the survival, growth and yield of young replanted apple trees. The quick and correct diagnosis of biotic and abiotic causes of the problem and the management through bio-control agents as they are eco-friendly and possess the long fertile life of the soil. This problem can be controlled at replanting orchard sites by integrated management practices. The soil



Growth of 'Super Chief' on *(a)* M.793, *(b)* MM.111, *(c)* M.7, *(d)* Seedling rootstocks after response to *Trichoderma viride*



Growth of 'Super Chief' on *(a)* M.793, *(b)* MM.111, *(c)* M.7, *(d)* Seedling rootstocks after response to soil fumigation with Formaldehyde

fumigation and solarization have been found somewhat more effective, but due to the complex nature of the problem, the combined use of chemical, cultural and biological methods could be beneficial in controlling the disease. Use of certain resistant clonal rootstocks and selection of right scion and rootstock combination as per the agro-climatic conditions may also be helpful in controlling this problem.

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