

## Sustainable land management of apple replant sites of Himachal Pradesh

Apple replant problem is a major issue in all apple growing areas of world including India. Due to small land holdings and difficult land terrain in Himachal Pradesh, it is impossible for apple orchardists to shift the plantation sites. Most of the apple orchards have completed their life span (40-50 years old) and these old orchard sites when replanted with the same crop, farmers face a lot of problems in terms of establishment of new plantation, poor growth, and sensitivity towards different soil borne pathogens and reduction in fruit yield. The main causes are soil pathogenic fungi, nematodes, nutrient exhaustion/loss, pH imbalances, heavy metal contamination and toxic root exudates of old apple trees. Chemical pesticides are used against soil pathogenic microbes but they sometimes target the plant beneficial microbes. Therefore, use of integrated sustainable land management strategies which are economical, environment friendly both to the plants and human beings are discussed in the present article to overcome the apple replant issue.

APPLE (*Malus domestica*) is the most important cash crop in temperate regions of the world. In India, it is grown in Himachal Pradesh, Uttarakhand and Jammu & Kashmir. It is most intensive monoculture crop grown in Himachal Pradesh. In Himachal Pradesh, most of the apple orchards are approximately 40-50 years old and need to be replanted as they are suffering from biotic (different soil pathogens like *Dematophora necatrix*, *Phytophthora cactorum*, *Pythium*, *Rizoctonia*, *Sclerotium* and *Fusarium*) and abiotic stresses (changes in soil pH, nutrient imbalances, accumulation of toxins in older roots), also showing symptoms of declining productivity. Due to difficult land terrain and small land holdings, replantation

of old apple orchard sites are the only option for farmers as horticulture is the mainstay of economy. Monocropping results in exhaustion of important soil nutrients, pH changes, shifts in soil microflora etc. affecting the fruit vitality and quality. As a result, a general decline in the growth and productivity of senile apple orchard is commonly observed. Therefore, these orchards have been compelled to replantation which is uneconomical. The new apple rootstocks/seedlings when replanted in these old orchards sites face difficulty in establishment, once established have retarded growth, poor root system, low grade quality fruits etc. The senile apple orchard management is going in a wider scale throughout the



Dead apple rootstock of previous year



Microbial consortia

**Table 1.** Effect of different agriculture practices on soil pathogenic fungi

Soil practice	Soil fungi ( $10^2 \times$ cfu/g soil)		Soil bacteria ( $10^6 \times$ cfu/g soil)		Soil pH	
	Before	After	Before	After	Before	After
Soil fumigation	42	37	8	18	5.2	6.7
Soil solarisation	39	34	10	19	6.0	6.9
Mixed cropping	38	34	6	15	5.8	6.0
Crop rotation	32	29	8	16	6.1	6.8

world but due to varied disease severity, fields, type of soil, presence of different pathogenic microbial species in the rhizosphere and abiotic factors like change in pH, nutrient imbalances, toxins etc. make its management a difficult task. Therefore, the present article describes the integrated approach including different sustainable practices like use of biofumigants (brassica seed meal, green leafy vegetables of cruciferous residues), soil solarisation and treatment of study site with microbial consortia (having biocontrol and probiotic potential) before and after plantation to manage this multifactor problem.

#### Integrated management strategies to control apple replant problem

Integrated management includes preplant soil biofumigation through brassica seed meal and green cruciferous residues, soil solarization, use of different cropping pattern, use of replant resistant apple varieties and application of microbial bioformulations to resolve the replant problem.

#### Preplant soil biofumigation by organic amendments

Different organic and green waste like brassica seed meal (BSM), fresh chopped leaves of cruciferous crops rich in glucosinolates which release bioactive compounds are widely used in soil as biofumigant to suppress/kill the soil-borne pathogens of apple replant disease. These are very good alternative to chemicals. BSM contain 10 times more glucosinolates and upon disruption and hydrolysis can release GSL-degradation products specifically isothiocyanates. BSM also serves as the source of nitrogen and alter the soil biology which helps in suppression of

plant pathogens like a decrease in soil fungal population (Table 1).

#### Soil solarization

Soil solarization is a physical method of soil-disinfestation by mulching a soil with a transparent polyethylene (25 micron) sheet in the month of May to June when temperature is very high, which helps to control soil borne pests (Table 1).

#### Intercropping/mixed cropping

Intercropping of *Allium fistulosum*, *T. aestivum*, *B. juncea* in between apple plantation helps in increasing the bacterial population and have antagonistic effect on apple replant disease organisms or reduction in number of soil fungi. This has positive effect on soil enzymatic activities like urease, phosphatase and dehydrogenase. Wheat cultivation prior to apple plantation increased the plant growth promoting fluorescent *Pseudomonas* spp. in the orchard soil and have growth promotional effect on apple plantation. Mixed cropping also decreased the effect of phenolic acids (root exudates of old apple trees) in the replanted soil. Application of *Brassica napus* seed meal enhanced the population of resident soil microflora thus controlling *Rhizoctonia solani* infection (Table 1).

#### Crop rotation

Crop rotation has a positive effect on improving soil physical and chemical properties besides regulating the soil structure. Crop rotation for more than one year has positive effect on nutritional content of soil as well as soil pathogenic microflora. Root volatile substances secreted

**Table 2.** Effect of different practices on soil microbial population before and after the experiment

Treatment	Bacteria ( $10^6 \times$ cfu/g soil)		Fungi ( $10^2 \times$ cfu/g soil)		Actinomycetes (cfu/g)	
	Before	After	Before	After	Before	After
T <sub>1</sub> (control)	4.0	11	32	37	0	0
T <sub>2</sub>	3.0	36	42	27	1.0	3.0
T <sub>3</sub>	5.0	33	37	21	2.0	4.0
T <sub>4</sub>	4.0	32	39	17	3.0	7.0
T <sub>5</sub>	6.0	41	40	18	0	6.0
T <sub>6</sub>	8.0	62	39	8.0	0	8.0
T <sub>7</sub>	5.0	67	41	5.0	1.0	12

\*cfu/g of soil at  $10^6$  dilution for bacteria and actinomycetes while  $10^2$  dilution for fungi



Root dip treatment



Response of integrated management practices on new apple rootstocks planted in old orchard sites of district Shimla, Himachal Pradesh



by *Allium fistulosum*, *Brassica juncea* and *Triticum aestivum* inhibited the mycelial growth and spore germination of *Fusarium* spp. (Table 1). Thus the use of these three crops helps in alleviating apple replant problem effects. The dimethyl disulfide and diallyl disulfide compounds released by *Allium* plants inhibit soil borne pathogens such as *Pythium ultimum* and *Fusarium oxysporum*. The secretion of different toxic compounds by old apple roots such as phenolic acids and phloridzin, promote the hyphal growth of ARD organism, *F. oxysporum* in continuous cropping soil and inhibited the growth of *Malus* seedlings. Crop rotations alone can continually reduce the phenolic acids in the soil.

#### Use of replant resistant apple rootstocks

Apple seedlings planted in replant sites showed symptoms of under developed growth pattern, stunting and root discoloration, whereas, use of apple resistant rootstocks are more helpful in lowering the effect of replant disease.

Overall, different practices help in reduction of soil pathogenic fungi thus maintaining the soil ion exchange capacity and ultimately improved the bacterial population which are the key indicators of successful establishment of apple plantations in the replanted sites.

#### Use of microbial bioformulations

Microbial bioformulations have several advantages over chemical fertilizers as they are store house of plant probiotics, long term sustainable, eco-friendly in nature and are future needs of agriculture. These have plant growth promoting effect on host plants as well as antagonistic effect against plant pathogenic fungi. Different bacterial genera used as bioinoculants are *Stenotrophomonas maltophilia*, *Pseudomonas aeruginosa*, *Acinetobacter seifertii*, *Bacillus megaterium*, *Bacillus subtilis* and *Bacillus licheniformis* etc. The liquid bioformulations are used for treating the pit soil for 5-6 days with 200-300 mL of each bacterial formulations. Roots were also dipped for half an hour in these formulation before plantation.

After plantation, the rhizospheric soil was drenched with 150-200 mL of respective bacterial formulation. They can be repeated at an interval of 30 days and applied for 8-9 months till the establishment of new apple plantation as these bacteria have root colonizing properties which help in the establishment of young plantation. A inverse relationship between bacteria and soil pathogenic fungi after repeated application of microbial formulations was observed. The bacterial population increased after eight months of cyclic application which are the key indicators of successful establishment of apple plants in replanted sites (Table 2).

#### SUMMARY

Apple replant problem is a burning issue in all apple growing areas of world. Both biotic and abiotic factors play a crucial role in poor establishment of the old apple replant sites. The symptoms includes poor establishment, stunted growth, poor quality fruit production, disease sensitivity etc. Integrated management strategies are helpful in reducing the effect on old apple replant sites. Integrated management includes use of chemical, biological and physical management strategies, but due to the harmful effect of chemical pesticides on soil healthy microflora and human health, the approaches should be environment friendly, economical and sustainable in nature. Sustainable management strategies like preplant soil fumigation through organic amendment, soil solarization, crop rotation, intercropping/ mixed cropping and use of replant resistant apple rootstocks are helpful in combating this problem.

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