www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating 2017: 5.03
TPI 2017; 6(12): 288-293

www.thepharmajournal.com
Received: 04-10-2017
Accepted: 05-11-2017

Niranjan Singh
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan Himachal Pradesh, India

DP Sharma
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan Himachal Pradesh, India

Rajesh Kaushal
Department of Soil Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan Himachal Pradesh, India

Correspondence
Niranjan Singh
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan Himachal Pradesh, India

Controlling replant disease of apple in Himachal Pradesh, India by rootstocks and soil agro-techniques

Niranjan Singh, DP Sharma and Rajesh Kaushal

Abstract
Apple orchards planted in late sixties in Himachal Pradesh and North Western Himalayan region have shown symptoms of declining productivity as these plants have completed their economic life span. Due to limited land and choice of crops for smaller micro climatic niches and incomparable economic equivalence of other fruits with apple, orchardists are compelled to replant old apple orchard sites. There has been substantial increase in the proportion of declining orchards which need to be changed. Therefore, standardization of suitable agro-techniques to combat replant problem in apple for better field survival rate and productivity under replant conditions in order to sustain the apple industry in the state. In present study there were 20 treatments comprising of four apple rootstocks i.e. Seedling, M.793, MM.111 and M.7 and five different soil treatments i.e. control, soil fumigation, PGPR, biocontrol and combined (Soil fumigation + PGPR + Biocontrol) with three replications. The data over the years 2015 and 2016 reveled that M.793 rootstock had significantly maximum plant growth parameters and soil microbial counts. Among the treatments, highest growth and vigour parameters and microbial counts were recorded maximum in combined treatment. The interaction between rootstocks and treatments revealed that combinations of M.793 × combined treatment recorded maximum growth and vigour traits, bacterial counts, fungal counts and actinomycetes counts compared to other rootstocks and treatment combinations under replant situations, which can be exploited for the management of replant problem in apple.

Keywords: Apple, Biocontrol, Microbial counts, PGPR, Replant Sick Soil, Rootstocks

1. Introduction
Apple (*Malus* × *domestica* Borkh.) is mainly grown in north Western Himalayan region which include states of Jammu and Kashmir, Himachal Pradesh, Uttrakhand, North Eastern hilly states and south Nilgiri hills in India. It is grown over an area of 277 (in '000 ha) with annual production of 2242 (in '000 MT) and productivity of 8.0 MT (NHB, 2016) [1]. Apple orchards planted in early sixties have shown symptoms of declining productivity as these plants have completed their economic life span. With increasing population and adverse environmental factors the land resource is shirking. Due to limited land resources and choice of crops for diversification in hill states, orchardists are compelled to replant old apple orchard sites with apple, which lead to drastic economic loss not only due to uprooting of old trees but also because of poor establishment of new plantations on the same site. Repeated cultivation of the same plant species on the same field is the primary factor leading to replant problems. As a result, a general decline in the growth and productivity of replanted apple orchards is commonly observed.
Apple replant disease (ARD) is a complex syndrome that occurs in young apple trees in replanted orchard sites (Mai and Abawi, 1981) [2]. Apple replant problem, though reported in the literature for more than century, has yet to have its causes clearly defined. Decline in apple productivity has been attributed to fungi, bacteria, nematodes, toxic agents, insect-pests, nutritional disturbances, enzymatic activates and chemical residues (Benizri *et al.*, 2005) [3]. The reasons for low productivity could be many but one of the most important reasons is age of orchards. In general, apple orchards of more than 40-50 years age have shown much more unfruitfulness than the young orchards. Most of apple orchards in Himachal Pradesh planted during sixties have either outlived their economic bearing life or declined due to the adverse effect of insect pests and diseases. This practice makes plants vulnerable to replant problem. There has been increasing concern about poor growth of apple trees planted at sites where apple tree grew before.

The situation resulting in this poor growth is generally known as replant problem (Utkhede and Smith, 1994) [4]. Therefore standardization of agro-techniques with integration of various management tools such as rootstocks, soil sterilization, biocontrol and PGPR is important to combat or reduce apple replant problem in old apple orchards (Haas and Defago, 2005 and Leinfelder and Merwin, 2006) [5, 6]. After several years, trees may recover from the initial growth depression and eventually reach the size and annual yields of unaffected trees Foy *et al.*, 1996) [7].Despite this partial recovery, cumulative yields and profitability in ARD-affected orchards usually remain lower than in unaffected orchards (Peterson and Hinman, 1994) [8]. There has been substantial increase in the proportion of declining orchards which need to be changed. Therefore, standardization of suitable agro-techniques to combat replant problem in apple for better field survival rate and productivity under replant conditions for sustainability of apple industry in the state.

2. Materials and methods

2.1 Location and Climate

The experiment was laid out at an elevation of 1250 m above mean sea level at 30° 51'N latitude and 76° 11'E longitude in the Department of Fruit Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The experimental site lies under the sub-temperate, sub-humid mid-hill agro climatic zone II of Himachal Pradesh where, summer is moderately hot during May-June while, winter is quite severe during December-January. The annual rainfall ranges between 110-120 cm and the major amount of which is received during June to September.

2.2 Rootstocks establishment

One year old uniform seedling and clonal rootstocks namely seedling, M.793, MM.111 and M.7 were planted in black polythene bags (18″ × 9″ size) containing a mixture of soil, FYM and sand (2:1:1). The optimum level of moisture was maintained in the growing media of polybags by regular irrigation. Planting was done under natural condition, in first week of February, 2014.

2.3 Materials and Treatments

The suitable methodology has been used to understand the response of apple seedlings and clonal rootstocks to replant soil. One year old polybag raised four rootstocks i.e. M. 793, MM.111, M.7 and Seedling were planted in 50 liters plastic container and filled with soil and FYM (3:1) along with soil ball and application of five soil management treatments viz., control (No treatment), soil fumigation (with formaldehyde), PGPR (*Bacillus licheniformis* CK-1), biocontrol (*Trichoderma viride*) and combined (Soil fumigation + PGPR + Biocontrol) in Completely Randomization Design under open field conditions, in first week of January, 2015. These rootstocks were grafted with 'Super Chief' in March 2015.

2.4 Soil Fumigation and Planting

Soil from replanted orchard site at Habban was brought to the experiment field of Department of Fruit Science. A heap of soil was sterilized with formalin (1:9) formaldehyde solution and covered under polythene sheet for three weeks. Afterword the soil heap was opened and worked in such a way to exclude formaldehyde fumes from soil. After two weeks the manures were mixed and soil filled in 50 litres plastic container along with polybag raised seedling and different clonal rootstocks.

2.5 Time of application: (Bacillus licheniformis CK-1 and Trichoderma viride)

Plant Growth Promoting Rhizobacteria [(PGPR) 250 ml] and Bio control [(*Trichoderma viride*) 100 gm] were applied at the time of planting in pots and then repeated after every three months up to December 2016.

2.6 Detection of rhizosphere microbial counts

Microbial counts was performed by standard plate counts technique, Wollum, (1982) [9] by employing different media for different groups of microorganisms.

Suspension of 0.1ml from dilution blank was spread over pre-poured solid media *viz.*, Nutrient Agar, Jensen medium, Jensen, (1987) [10] and Pikovskaya's medium, Pikovskaya, (1948) [11] with the help of glass spreader under aseptic conditions for enumeration of bacteria, free nitrogen fixing bacteria and phosphate solubilizing bacteria, respectively. Plates were incubated in inverted position at 28±2°C for 48 hours. After the incubation period, the microbial counts was expressed as colony forming unit per gram of soil ($cfug^{-1}$ soil).

2.7 Plant Growth traits

2.7.1 Plant height

The plant height was measured from the ground level to the top with the help of a graduated scale and mean was worked out and expressed in centimeters (cm).

2.7.2 Number of feathers

Total number of branches per plant were countsed in each plant and treatment.

2.7.3 Leaf area

Ten fully expanded mature leaves were taken from each replication of each treatment. The leaf area was measured with the help of portable Laser (CI- 202), CID Bio-Science leaf area meter and average leaf area of each treatment was calculated and expressed as square centimeter (cm^2).

2.7.4 Plant volume

The total above ground plant volume of each plant was calculated from the data on height and spread measurements according to the formulae suggested by Westwood, (1978) [13] and was expressed in cubic meters (m^3).

i) For a tree that was taller than wide (Prolate Spheroid),

Volume = $4/3\ \pi ab^2$

ii) For a tree that was wider than tall (Oblate Spheroid),

Volume = $4/3\ \pi a^2 b$

Where,

$\pi = 3.14$

a = ½ the major axis (height)

b = ½ the minor axis (spread)

2.8 Statistical analysis

Data on plant growth and soil microbial counts of replanted apple to determine the significance of differences analyzed by using Randomized Block Design (RBD)-two way analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) [13]. In addition to show the interrelationships between rootstocks in combination with soil management treatments and mean values of each studied plant growth and soil

microbial counts statistical analysis program (SPSS) was used.

3. Results and discussion

3.1 Microbial counts

There was a big difference in growth and soil biological activities between rootstocks and treatments into control with sick soil, with those in rootstocks and treatments displaying significantly (*P< 0.05*) higher growth and microbial counts in replant sick soil over the two years. Among the treatments, maximum bacterial counts (106.31 10^5cfu/g soil), fungal counts (16.21 10^4cfu/g soil) and actinomycetes counts (14.28 10^2cfu/g soil) during 2015 was recorded in combined treatment. Similarly in 2016, highest bacterial counts (109.10 10^5cfu/g soil), fungal counts (15.21 10^4cfu/g soil) and actinomycetes counts (13.84 10^2cfu/g soil) were recorded in combined treatment, compared to other treatments however, minimum in control. The highest actinomycetes counts (13.96 10^2cfu/g soil) was found in control and lowest in biocontrol (Table 1 and 2). Different rootstocks did not show consistent influence on rhizobacterial, fungal and actinomycetes counts during both the years of study (Table 3). The interaction between rootstocks and treatments was found to be non-significant in respect of rhizobacterial, fungal and actinomycetes counts during 2015 and 2016. Numerically, all other rootstocks registered higher rhizobacterial, fungal and actinomycetes counts with combined treatment combinations (Figures 5 to 7, respectively).

Present study indicates that the enzyme activates of apple soil was increased with the application of combined treatment (Soil fumigation + PGPR + *Trichoderma viride*) and M.793 rootstock. Kumar *et al.,* (2014) [14] also reported that the combined application of indigenous PGPR (*B. megaterium*, *A. chlorophenolicus* and *Enterobacter*) significantly increased 17.5%, 79.8%, 78.6% and 26.7% plant height, grain yield, straw yield and test weight under pot condition and also 29.4%, 27.5%, 29.5% and 17.6% under field conditions which supported our results. These findings are also in conformity with those of Jarak *et al.,* (2012) [15] who also reported the ability of *Trichoderma viride*, *Pseudomonas* sp., *Bacillus* sp. and *Azotobacter chroococcum* strain to enhance maize growth (*Zea mays* L.) under field conditions. These results are also in line with those obtained by Kaur and Reddy, (2015) [16] who found that the highest yield was obtained by bio-inoculation of treatments singly or together with biofertilizer in maize-wheat cropping system. The results are further supported by the findings of Gaind et al. (2006) [17] who also reported that incorporation of compost prepared from paddy straw and fungal inoculants in wheat improved enzymatic activities and phosphorous content of soil. These findings are also in conformity with those of Kaur and Reddy [16] who also reported that inoculation of PSB together with rock phosphate fertilizer increased the crop growth parameters (shoot height, shoot and root dry biomass) and grain yield of wheat. Inoculation with AM fungi enrich soil microbe quantities, equilibrate proportion of various microbes, maintain a stabilization of proper proportion of the microbes, enhance soil carbon, nitrogen, and phosphorous cycling power, thus improve the soil enzyme activity (Zhao et al., 2010) [17].

3.2 Plant Growth traits

In the present study, different rootstocks and soil management treatments recorded significant increase in plant growth and soil biological activities. Among the rootstocks, M.793 rootstock had significantly higher increase in plant height (165.67 cm), number of feathers (3.51), leaf area (39.71 cm^2) and plant volume (1.40 m^3) during 2015 while, in 2016 maximum in plant height (193.17 cm), number of feathers (6.79), leaf area (40.42 cm^2) and plant volume (1.64 m^3) however, minimum in seedling rootstock (Table 4). Among the treatments, plant height (184.16 cm), number of feathers (3.45), leaf area (46.12 cm^2) and plant volume (1.87 m^3) during 2015 while, in 2016 in plant height (223.13 cm), number of feathers (7.12), leaf area (46.73 cm^2) and plant volume (2.27 m^3) were recorded maximum in combined treatment, compared to other treatments however, minimum in control (Table 2). Among the rootstocks and treatment combinations of combined treatment × M.793 rootstock recorded maximum plant height (201.32 cm), number of feathers (4.78), leaf area (48.32 cm^2) and plant volume (2.22 m^3) during 2015 while, in 2016 highest in plant height (251.68 cm), number of feathers (8.03), leaf area (48.70 cm^2) and plant volume (2.78 m^3) compared to other rootstock and soil treatment combinations given in figures 1 to 4, respectively.

Seedling rootstock was found to be more sensitive to replant problem because of their susceptibility to soil borne disease in particular. In general, replant sites have more pathogens, thereby, directly affecting the plant growth and development of new saplings. Comparatively, the clonal rootstocks (M.793, MM.111 and M.7) have been reported to be more tolerant to soil borne diseases (Andreev, 1984 [18] and Kviklys *et al.*, 2007 [19]) and have more biomass of adventitious roots. Production of plant growth regulators such as auxin, gibberellins and cytokinins by the plant growth promoting rhizobacteria has been suggested as possible mechanisms of action affecting plant growth. The findings are in line with reports of (Thakur, 2017 [20], Ferree and Warringon, 2003 [21], Rana and Chandel, 2003 [22], Karlidag *et al.*, 2007 [23], Kirad *et al.*, 2009 [24], Tripathi *et al.*, 2014 [25], Kipkoriony and Fusao, 2006 [26]) who also recorded increased plant height and spread with the application of plant growth promoting rhizobacteria and *Trichoderma viride*.

Rumberger *et al.* (2004) [27] reported that apple rootstock genotype had a stronger effect on the rhizosphere soil microbial community composition than did the pre-plant soil treatments in soils. We found that 2 years later, rhizosphere communities of bacteria, fungi, and actinomycetes still clustered roughly together by rootstock genotype (Fig. 8 to 10, respectively). Plant species specific rhizosphere microbial communities have been reported widely (Marschner *et al.*, 2001 [28], Miethling *et al.*, 2000 [29], Westover *et al.*, 1997 [30]) as have changes in rhizosphere microbial communities due to intra-specific variation (Carelli *et al.*, 2000 [31], Cattelan *et al.*, 1998 [32], Di Giovanni *et al.*, 1999 [33]). In our experiment, the same scion variety ('Super chief') was grafted onto four different apple rootstocks. The rhizosphere of M.793 had the highest culture able soil bacteria counts compared with the other rootstocks, and this rootstock also produced the highest plant growth during 2015 and 2016. In our experiment, rootstocks strongly affected rhizosphere microbial community composition (Fig. 8 to 10, respectively). This suggests that rhizosphere fungi and bacteria communities may be more influential in the promulgation or suppression of ARD than bacteria and oomycetes at this site. These findings are similar to those of Mazzola that also implicated the involvement of fungi and *Pseudomonas* in ARD (Gu and Mazzola, 2003 [34], Mazzola, 1997 1998 [35]). Rootstocks were not only a main

factor contributing to observed changes microbial composition in the rhizosphere, but were also a dominant factor for tree growth and yield. Rootstock genotype selection is thus a promising alternative for managing ARD (Shengrui *et al.*, 2006) [36].

Table 1: Effect of soil agro-techniques on microbial counts in declining apple orchard sick soil (Pot culture)

Treatment	Bacterial count (10^5cfu/g soil)		Fungal count (10^4cfu/g soil)		Actinomycetes count (10^2cfu/g soil)	
	2015	2015	2016	2015	2016	2016
Control	96.38^{d}	13.29^{c}	13.44^{c}	13.29^{c}	13.44^{c}	13.96^{a}
Soil fumigation	93.60^{e}	13.71^{cb}	13.27^{c}	13.71^{cb}	13.27^{c}	12.96^{c}
PGPR	104.13^{b}	14.21^{b}	14.46^{b}	14.21^{b}	14.46^{b}	12.96^{c}
Biocontrol	95.87^{c}	15.86^{a}	13.46^{c}	15.86^{a}	13.46^{c}	12.71c
Combined	106.31^{a}	16.21^{a}	15.21^{a}	16.21^{a}	15.21^{a}	13.21^{b}

Degree of significance of ($P \leq 0.05$)

Table 2: Effect of soil agro-techniques on plant growth traits in declining apple orchard sick soil (Pot culture)

Treatment	Plant Height		Leaf area		Number of feathers		Plant volume	
	2015	2016	2015	2016	2015	2016	2015	2016
Control	134.21^{e}	152.83^{e}	34.30^{c}	34.55^{c}	2.20^{c}	4.01^{d}	0.75^{e}	0.86^{e}
Soil fumigation	145.52^{d}	163.79^{d}	34.30^{c}	34.68^{c}	2.40^{c}	4.77^{c}	0.94^{d}	1.06^{d}
PGPR	161.53^{b}	180.15^{b}	38.24^{b}	39.78^{b}	3.00^{b}	6.52^{b}	1.26^{b}	1.41^{b}
Biocontrol	157.80^{c}	174.94^{c}	38.12^{b}	39.28^{b}	2.90^{b}	6.22^{b}	1.12^{c}	1.24^{c}
Combined	184.16^{a}	223.13^{a}	46.12^{a}	46.73^{a}	3.45^{a}	7.12^{a}	1.87^{a}	2.27^{a}

Degree of significance of ($P \leq 0.05$)

Table 3: Effect of different rootstocks on microbial count in declining apple orchard sick soil (Pot culture)

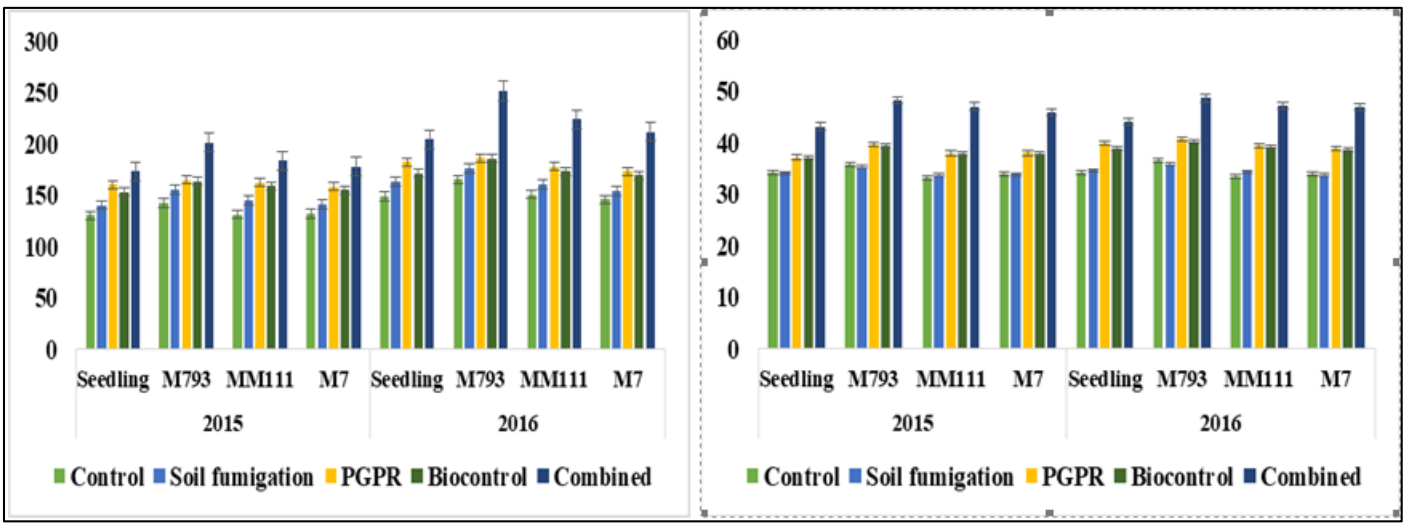
Rootstocks	Bacterial count (10^5cfu/g soil)		Fungal count (104cfu/g soil)		Actinomycetes count (10^2cfu/g soil)	
	2015	2016	2015	2016	2015	2016
Seedling	96.28	100.30	14.42	13.42	13.52	11.94
M.793	102.56^{a}	100.50	14.62	13.85	13.91^{a}	13.08
MM.111	99.36	101.46	14.99^{a}	14.20	13.22	14.13^{a}
M.7	98.83	100.80^{a}	14.60	14.40^{a}	12.85	12.88
LSD	NS	NS	NS	NS	NS	NS

Degree of significance of ($P \leq 0.05$)

Table 4: Effect of different rootstocks on microbial count and growth traits in declining apple orchard sick soil (Pot culture)

Rootstocks	Plant Height		Leaf area		Number of feathers		Plant volume	
	2015	2016	2015	2016	2015	2016	2015	2016
Seedling	151.52^{c}	174.15^{b}	37.22^{c}	38.40^{b}	2.51^{c}	4.93^{c}	1.08^{c}	1.25^{c}
M.793	165.67^{a}	193.17^{a}	39.71^{a}	40.42^{a}	3.51^{a}	6.97^{a}	1.40^{a}	1.64^{a}
MM.111	156.35^{b}	177.59^{b}	38.00^{b}	38.72^{b}	2.70^{b}	5.63^{b}	1.17^{b}	1.34^{b}
M.7	153.02^{c}	170.97^{c}	37.93^{c}	38.48^{b}	2.43^{c}	5.39^{b}	1.11^{c}	1.24^{c}

Degree of significance of ($P \leq 0.05$)



(1) (2)

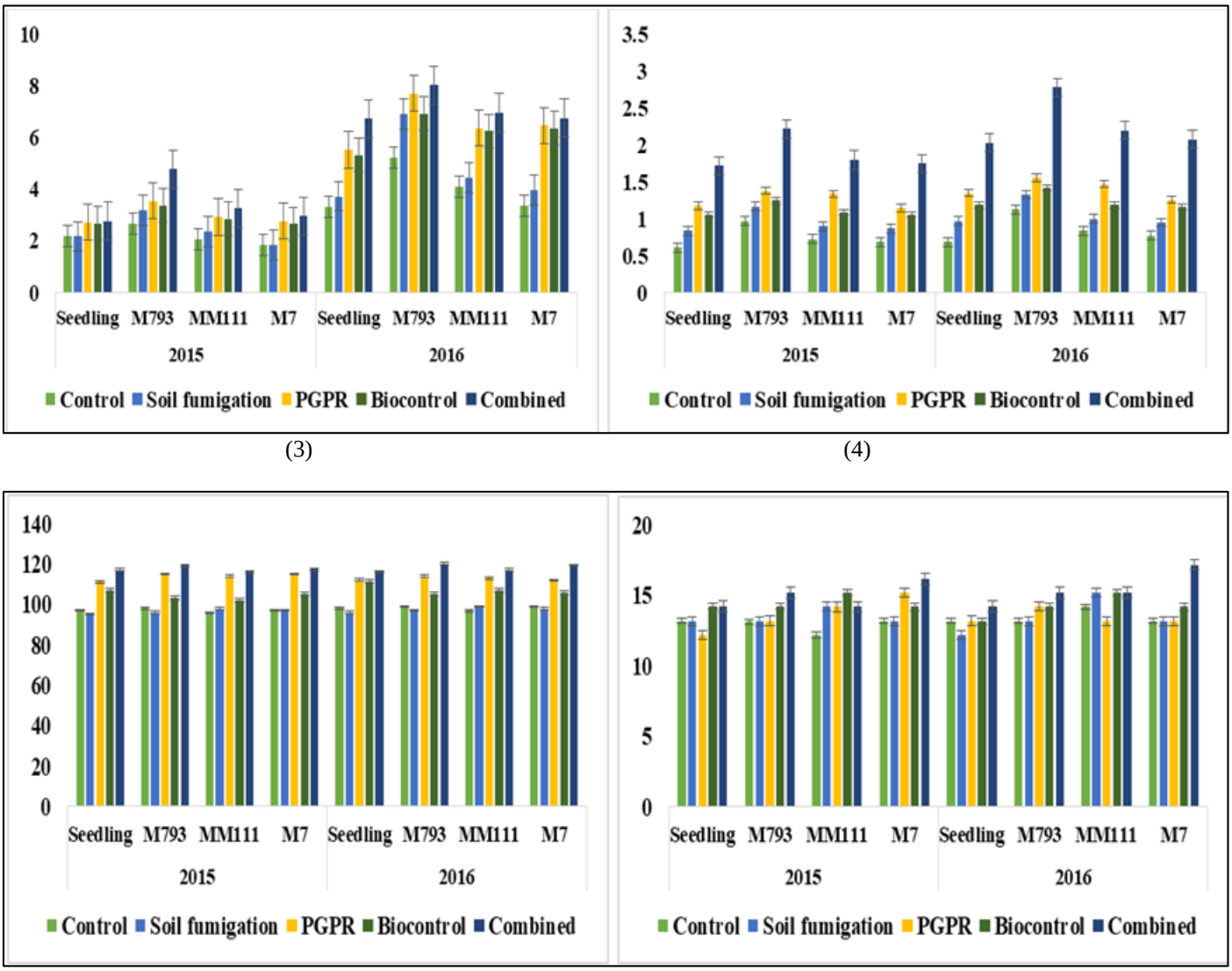


Fig 1: Effect of different rootstocks and treatments on plant height (1), leaf area (2), number of feathers (3), plant volume (4), bacterial count (5) and fungal count (6) of replanted apple. Vertical bar represent mean of three replication ± SE m and LSD ($p \leq 0.05$).

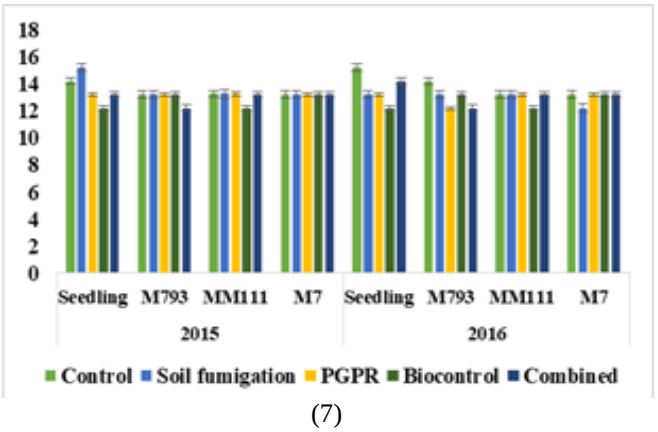


Fig 2: Effect of different rootstocks and treatments on actinomycetes count (7) of replanted apple. Vertical bar represent mean of three replication ± SE m and LSD ($p \leq 0.05$).

4. Conclusion

From the present investigation it can be concluded that M.793 is most suited apple rootstock for replantation. The combined treatment (Soil fumigation +PGPR +Biocontrol) is an appropriate soil agro-technique to mitigate replantation problem in apple. The consortium of M.793 rootstock × combined treatment recorded significant increase in plant growth and soil biological activities under replant sick soil. Most of growth and soil biological activities had positive correlation with plant volume in present study.

5. Acknowledgements

Authors are highly thankful to the facilities and funds provided by Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan 173 230 (H.P.) India and Mission for Integrated Development of Horticulture (MIDH), Govt. of Himanchal Pradesh.

6. References

1. National Horticulture Board (NHB). Indian Horticulture Database, http://www.nhb.org, 2016.
2. Mai WF, Abawi GS. Controlling replant diseases of pome and stone fruits in Northeastern United States by a replant fumigation. Plant Diseases. 1981; 34:254-267.
3. Benizri E, Piutti S, Verger S, Pages L, Vercambre G, Poessel JL, Michelot P. Replant diseases: bacterial community structure and diversity in peach rhizosphere as determined by metabolic and genetic fingerprinting. Soil Biology and Biochemistry. 2005; 3:1738-1746.
4. Utkhede RS, Smith EM. Biotic and abiotic causes of

replant problems of fruit trees. Acta Horticulturae. 1994; 363:25-31.
5. Haas D, Defago G. Biological control of soil borne pathogens by fluorescent pseudomonads. Nature Reviews Microbiology. 2005; 3:307-319.
6. Leinfelder M, Merwin IA, Rootstock selection pre plant soil treatment and tree planting partitions as factors in managing apple replant disease. Horticulture Science. 2006; 41:394-401.
7. Foy CL, Dark CR, Pirkey CL, Impact of herbicide applied annually for 23 years in a deciduous. Weed Technology. 1996; 10:587-591.
8. Peterson AB, Hinman RH, The economics of replanting apple orchards in Washington state. Acta Horticulture. 1994; 363:19-23.
9. Wollum AG, Cultural methods for soil microorganisms. In*:* Methods of Soil Analysis, Part II, Chemical and Microbiological properties. American Society of Agronomy. 1982; 781-802.
10. Jensen ES. Inoculation of pea by application of Rhizobium in planting furrow. Plant and Soil. 1987; 97:63-70.
11. Pikovskaya RI, Mobilization of phosphorus in soil in connection with the vital activity of some microbial species. Mikrobiologiya. 1948; 7:362-370.
12. Westwood MN. Plant efficiency; growth and yield mesurments. In: Temperate Zone Pomology. W H Freeman and company, San Fransisco. 1978; 119-120.
13. Gomez KA, Gomez AA. Statistical procedure for agricultural research. IInd ed. John Wiley and Sons, New York. 1984; 357-427.
14. Kumar A, Maurya BR, Raghuwanshi R. Isolation and characterization of PGPR and their effect on growth, yield and nutrient content in wheat (*Triticum aestivum* L.). Biocatalysis and Agricultural Biotechnology. 2014; 3:121-128.
15. Jarak M, Mrkovacki N, Bjelic D, Josic D, Jafari TH, Stamenov D. Effects of plant growth promoting rhizobacteria on maize in greenhouse and field trial, African Journal of Microbiology Research. 2012; 6: 5683- 5690.
16. Kaur G, Reddy MS, Effects of phosphate solubilizing bacteria, rock phosphate and chemical fertilizers on maize-wheat cropping cycle and economics. Pedosphere. 2015; 25:428-437.
17. Zhao M, Li M, Liu RJ, Effects of arbuscular mycorrhizae on microbial population and enzyme activity in replant soil used for watermelon production. International Journal of Engineering. Science and Technology. 2010; 2(7):17-22.
18. Andreev A. Vegetative and reproductive performance of the apple cultivar Starkrimson grafted on different rootstocks. Gradinarska Lozarska Nauka. 1984; 21:24-39.
19. Kviklys D, Lanauskas J, Sakalauskaite J, Kviklienė N, Uselis N. Soil exhaustion and rootstock effect on the growth of apple planting material. Agronomy Research. 2007; 6:511-516.
20. Thakur KK. Studies on replant problem in peach. PhD thesis, Dr. Y.S Parmar University of Horticulture and Forestry Solan Himanchal Pradesh. India, 2017.
21. Ferree DC, Warringon IJ. Apple botany, production and uses, D.C. Ferree and I.J. Warrington, CABI Publishing, USA, 2003.
22. Rana RK, Chandel JS. Effect of biofertilizer and nitrogen on growth, yield and fruit quality of strawberry. Progressive Horticulture. 2003; 35:25-30.
23. Karlidag H, Ahmet E, Metin T, Fikrettin S. Effects of root inoculation of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrient element contents of leaves of apple. Scientia Horticulture. 2007; 114:16-20.
24. Kirad KS, Barche S, Singh DB, Response of integrated nutrient management in strawberry (*Fragaria* × *ananassa* D.). Acta Hort. 2009; 842:653-656.
25. Tripathi VK, Mishra AN, Kumar S, Tiwari B. Efficacy of Azotobacter and PSB on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. Progressive Horticulture. 2014; 46:48-53.
26. Kipkoriony LR, Fusao M. Peach seedling growth in replant and non-replant soils after inoculation with arbuscular mycorrhizal fungi. Soil Biology & Biochemistry. 2006; 38:2536-2542.
27. Rumberger A, Yao S, Merwin IA, Nelson EB, Thies JE. 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. 2004; 264:246-260.
28. Marschner P, Yang CH, Lieberei R, Crowley DE. Soil and plant specific effects on bacterial community composition in the rhizosphere. Soil Biology & Biochemistry. 2001; 33:1437-1445.
29. Miethling R, Wieland G, Backhaus H, Tebbe CC. Variation of microbial rhizosphere communities in response to crop species, soil origin, and inoculation with Sinorhizobium meliloti L33. Microbial Ecology. 2000; 40:43-56.
30. Westover KM, Kennedy AC, Kelley SE. Patterns of rhizosphere microbial community structure associated with co-occurring plant species. Journal of Ecology. 1997; 85:863-873.
31. Carelli M, Gnocchi S, Fancelli S, Mengoni A, Paffetti D, Scotti C, Bazzicalupo M. Genetic diversity and dynamics of Sinorhizobium meliloti populations nodulating different alfalfa cultivars in Italian soils. Applied and Environmental Microbiology. 2000; 66:4785-4789.
32. Cattelan AJ, Hartel PG, Fuhrmann JJ. Bacterial composition in the rhizosphere of nodulating and non-nodulating soybean. Soil Science Society of America Journal. 1998; 62:1549-1555.
33. Di Giovanni GD, Watrud LS, Seidler RJ, Widmer F. Comparison of parental and transgenic alfalfa rhizosphere bacterial communities using Biolog GN metabolic fingerprinting and enterobacterial repetitive intergenic consensus sequence PCR (ERIC-PCR). Microbial Ecology. 1999; 37:129-139.
34. Gu YH, Mazzola M. Modification of fluorescent pseudomonad community and control of apple replant disease induced in a wheat cultivar-specific manner. Applied Soil Ecology. 2003; 24:57-72.
35. Mazzola M. Identification and pathogenicity of Rhizoctonia spp. isolated from apple roots and orchard soils. Phytopathology. 1997; 87:582-587.
36. Shengrui Y, Ian AM, George S, Abawib, Janice ET. Soil fumigation and compost amendment alter soil microbial community composition but do not improve tree growth or yield in an apple replant site. Soil Biology & Biochemistry. 2006; 38:587-599.