Evaluation of Different Fungicides Against *Phytophthora* Spp. Associated with Citrus Decline: A Review

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**Abstract**

There are several ways to manage plant diseases like use of resistant varieties, biological control agents, plant extracts, use of synthetic chemicals and integrated plant disease management. Among them, use of chemicals is most practised and easy way to manage plant diseases. There are many fungicides available in the market for this purpose. Fungicide like metalaxyl and mancozeb are effective to inhibit mycelial growth of *Phytophthora vignae* that causes root rot of cowpea. Fosetyl-Al gives good control against Phytophthora root rot when apply as foliar spray, sleeve drench to seedling or trunk injection to mature tree. Copper based fungicides completely inhibit the mycelial growth of fungi belong to class oomycetes. Mixture of mancozeb and fenamidone as well as copper octanoate and dimethomorph are effective to control *Phytophthora ramorum*.

**Keywords**: Citrus; Disease; Management; Fungicide; Effective

**Introduction**

Citrus is one of the most important fruit crops of the world that belongs to family Rutaceae, comprises of 130 genera and seven subfamilies [1]. It is cultivated in tropical and subtropical region of the world in near about 140 countries. It is thought that citrus were originated from china and other eastern region like Thailand, Malaysia and India. In Middle East, Europe, North Africa, turkey and Greece it was introduced by Alexander from India in fourth century BC [2]. With the passage of time citrus occupying all the continents, societies and cultures due to its lush green tree, beautiful flower and delicious fruit. Now a day’s world annual citrus production is near about 115 million tons. Brazil is at the top with more than 20 million tons production, China ranked second with 19.6 million tons and United States is the third largest producer with 10 million tons. Other important citrus producing countries are Mexico, India, Spain, Iran, Nigeria and Turkey [3] Major grown verities of citrus are oranges, mandarins, lime, and grapefruits. There are many cultivar of citrus available to grow but it is mainly classified into oranges, mandarins, tangerines, sour oranges, lemons, limes, grapefruit, pummelos and citron. Citrus is full of nutritional benefits, it is source of vitamin-C which help in absorption of iron, zinc and other foods. As compared to other fruits, citrus has higher contents of antioxidants which catalyse our immune system and also protects us from heart diseases and cancer. Citrus fruit contains good quantity of dietary fibre which improves food digestion and protect from constipation. Low level of sodium and high content of potassium are good to maintain normal blood pressure. Rich source of phytochemicals which protect human body from cancer, blood clotting and heart diseases as well as have anti-inflammatory properties. Flavonoids which are good against allergies, viral and fungal infection, inflammatory and heart diseases are also component of citrus fruit. Folate is a component of citrus fruit which helps in genetic stability and protect children from neural tube problem. Citrus fruit is good source of polyphenols which are good against viral infection and have anti-carcinogenic, anti-proliferative and anti-inflammatory properties [4].

**Evaluation of Fungicides**

Young et al. conducted experiments in USA, Australia and South Africa to manage *Phytophthora* root rot of avocado tree. Fosetyl-Al and phosphorous acid were applied through injection, sleeve drench and foliar spray. There were significant difference in result of Fosetyl-Al and phosphorous acid application. In South Africa fosetyl-al injection gave better result as compared to folia spray. There was improvement in affect when calcium buffer were used with Fosetyl-al. In case of phosphorous acid there
was decline after improvement in the start, Fosetyl-al treatment give significant recovery. In Australia there was 48% improve maintain plant health when Fosetyl-Al was used at 15ml/m of tree canopy for two times in period of 5 months. Response of Fosetyl-Al improved when zinc sulfate salt was added. In Florida and California result indicated that foliar spray was better than sleeve drench. Overall results indicated that Fosetyl-Al is effective in controlling Phytophthora root rot either applied by using sleeve drench, injection or foliar spray.

Fernando [5] evaluated metalaxyl, mancozeb, alicate and etridiazole fungicide to control Phytophthora vignae which causes root and stem rot of cowpea. P001 & P006 isolates of P. vignae were used. Metalaxyl gave maximum control under lab condition and in pot experiments. Inhibition of oogonia was also maximum in plates amended with metalaxyl. In greenhouse experiments there were no aerial symptoms on plants treated with metalaxyl. Dry shoot weight of non-inoculated control and plants treated with metalaxyl at rate of 10mg per litter was same, but roots dry weight was higher in plants treated with metalaxyl. Root disease severity was minimum when metalaxyl used at the rate of 100mg/L. Similar result were produced in stem disease severity control when alicate and mancozeb were used at the rate of 1000mg/L & 100mg/L respectively. Mancozeb was most effective when used as drench as compared to foliar spray. Etridiazole gave same result at 50mg/L as metalaxyl give at 10mg/L.

Lamour KH [6] discussed ethology of diseases affecting floriculture crops caused by Phytophthora parasitica and P. Drechsler. For isolation of pathogens samples were collected from 11 different production bases on the bases of apparent symptoms. Pathogen was isolated on BARP media. For purification a plug from colony shifted to petri plate containing water agar. Pathogen was identified to species level on the basis of morphological character, and sequencing of ribosomal DNA. These characters revealed that these were the isolates of P. drechsleri and Pnicotianae. There was genetic diversity among the isolates. In 68 markers from P. nicotianae 42 were monomorphic and 26 were polymorphic. Among the 64 AFLP markers from P. drechsleri 30 were monomorphic and 34 were polymorphic.

Wagner S [7] evaluated different fungicides to control Phytophthora ramorum causes disease in oak plant. Pathogen was isolated in Europe and USA from nurseries and plant grown in natural habitat. Nine fungicides were used, each fungicide were tested at seven different concentrations. Combination of mancozeb and fenamidone, copper-octanoate and dime-thomorph gave most significant result as they completely inhibited mycelial growth and zoosporangia germination. On the other hand, propagocarb, azoxy-strobin and cyto-fomid were least effective in zoospores germination and mycelial growth germination.

Hu JH [8] isolated from nurseries in Virginia, USA and evaluated mefenoxam sensitivity against it. More than 90 isolates that were isolated from nurseries of different crops and irrigated water in Virginia was used. Different isolates that were isolated from other crops were used for comparison. Fungicides were evaluated at the rate of 100ug/mL and then added to growth media at 50°C. Small agar disc containing pathogen was placed in the centre of petri dish containing poisoned media. Three replicate were used for each treatment. After inoculation plates were incubated for 5-7 days at 23°C in dark. Growth inhibition was measured after 7 days. For pot experiments, 7 sensitive and 9 resistant isolates were selected. After treatments with fungicides seedlings of geranium plants were inoculated with Phytophthora nicotianae. Mefenonam gave complete protection to seedling against sensitive isolates but mortality rate was same in non-treated control and plants treated with resistant isolates.

Tjøsvold SA [9] evaluated different fungicides against Phytophthora ramouram that infect different plants. Fungicides were evaluated on four genera of plants laurustinus, azalea, rhododendron and camellia. These plants were grown in green house where day time temperature was 73.5°C and night temperature was 51°C. Fungi were isolated from infected samples of rhododendron collected from nurseries located in California. Leaves of experimental plants inoculated with pathogen inoculum by placing 6mm plugs on wounded area. After development of lesions plants were treated with fungicides having different mode of action. Results show that different fungicides have different effect on different experimental plants. Residual effects of fungicides were also measured in this study.

Moayedi et al. [10] evaluated the antagonistic properties of Trichoderma spp. to control the root rot of sugar beet caused by Phytophthora spp. in Iran. For isolation of Trichoderma samples were collected from sugar beet field of Faris province. For isolation of Phytophthora spp. sample were collected from infected field. drechsleri and cryptogea were isolated. There were eight species of biocontrol agent that were tested against these pathogens. Different species of biocontrol agents were different in their ability to inhibit pathogen. In dual culture technique T. harzianum and T. atroviride were more efficient. In green house experiment T. harzianum strain was best to control disease. In addition to this experiment volatile and non-volatile metabolites were also tested against mycelial growth of pathogen.

Jagtap GP [11] evaluated different bioagent and plant extract to manage citrus gummosis caused by sp. in Maharashtra state of India. Neem, Acacia, Eucalyptus, Mehendi, Dhatura, Glyricida and Lantana were used for plant extracts. Leaves were collected from healthy plants, chopped into small pieces and ground with equal quantity of distilled water. Homogenised mixture obtained were evaluated at the rate of 100ug/mL and then added to growth media at 50°C. Small agar disc containing pathogen was placed in the centre of petri dish containing poisoned media. Three replicate were used for each treatment. After inoculation plates were incubated for 5-7 days at 23°C in dark. Growth inhibition was measured after 7 days. For pot experiments, 7 sensitive and 9 resistant isolates were selected. After treatments with fungicides seedlings of geranium plants were inoculated with Phytophthora nicotianae. Mefenonam gave complete protection to seedling against sensitive isolates but mortality rate was same in non-treated control and plants treated with resistant isolates.
Graham et al. [12] discussed success and challenges in managing diseases of citrus. Most serious disease was gummosis also known as foot rot in which pathogen infect scion near ground level. Damping off seedling also caused by spp. in which young seedling died. This pathogen also spoils the fruit by causing fruit brown rot. There are losses of 3-6% due to this pathogen. For management of diseases use disease resistant root stock, budding enough above the ground, planting well above the ground and proper drainage. In case of tolerant root stock effective fungicides would also be used. In mature groves proper drainage and use of effective fungicide is recommended to manage diseases. To manage brown rot of fruit use of phosphate fungicide before the appearance of early symptoms and after infection copper-based fungicides are good to use.

Cwalina Ambroziak B [13] conducted three-year field experiments to evaluate the effect of different chemical and biocontrol agent, on early potato cultivar health status. Different treatment consisted of different concentrations of biocontrol agent and chemicals were applied for three growing season. Before applying these concentrations in fields in vitro experiments were conducted to check the compatibility of biocontrol agent with chemicals. These experiments revealed the abilities of these treatments to control early and late blight of potato.

Mihajlovic M [14] discussed management of soil inhabiting pathogens. There is several soil borne pathogens that cause important economic losses. There are several method to manage these pathogens that are: crop rotation, use of chemicals, soil amendment, use of biological control agents, organic and inorganic mulches, soil solarisation, use of biochar, hydroponic technique for plant growth, use of resistant cultivars, soil fumigation and integrated disease management.

Adaskave JE [15] studied new mode of action and potassium phosphate resistance to manage citrus diseases caused by Phytophthora spp. in United States. Pathogen was isolated from infected fruit with brown rot symptoms, and was collected from orchard in California. Under Lab conditions, dilution method was used to assay sensitivity of potassium phosphate against pathogen at different EC value. For preharvest treatment, chemical sprayed 10 days before harvesting, after harvesting fruits were incubated with citrophthora and incubated at 20°C for eight days. Post-harvest treatments were applied after 8-24 hours of inoculation with pathogen. Results indicated that both pre and post-harvest treatments gave significant control over disease control.

Conclusion

Phytophthora spp. causes most serious and economically important diseases of citrus. Tree and crop production losses occur from nursery to fruit production. Disease caused by spp. are root rot, gummosis and brown rot of fruit. Most important species involve in citrus decline are P. citrophthora and P. nicotianae. Management of these diseases is necessary to reduce yield losses as well as to maintain fruit quality.

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