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Causes and Treatment of Drying Trees

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Introduction

Drying of both fruit trees (mango, citrus and guava) and non-fruit trees (*Dalbergia sissoo*, *Populus* spp., *Eucalyptus globulus*, *Melia azedarach*, *Acasia nilotica* and *Pinus* spp.) has become an acute problem in some South Asian countries like Pakistan, India, Nepal, Bhutan and Bangladesh.

Many workers (Bakshi, 1955, 1957, 1974, 1976; Bakshi *et al.*, 1957; Basak, 1994; Khan and Bokhari, 1970) in the past have made strenuous efforts to find out the real cause and to devise an effective treatment of this tree decline, but without any success. The failure of these workers may be attributed to the fact that they tried to assign a single cause to this menace, but actually it was a very complicated and complex cause, as will be seen in the following lines.

A lot of information necessary for the understanding of this problem is already available and lying scattered in the literature of different disciplines like Entomology, Plant Pathology, Agronomy, Plant Physiology, Soil Science, Forestry and Horticulture. Now the need was to gather this information at one place and to formulate the generalizations or to draw the conclusions in order to devise an effective control of the disease, as has been done in this work.

Causes: A number of environmental stresses, such as nutrient deficiency, extreme drought, flooding, waterlogging, soil salinity/sodicity, high temperature, insecticides, fungicides and herbicides, contribute directly or indirectly towards tree drying.

Nutrient deficiency: In sandy soils, the trees dry up due to the lack of nutrients, especially nitrogen.

Extreme drought: One of the damaging effects of drought is the concentration of salts within the plant cells subjected to water stress. These salts can damage the enzymes, which control metabolism and are thus essential to life. At high levels of stress, respiration, CO_2 assimilation and translocation of assimilates drop to levels near zero and thus the trees dry. The trees usually recover from this stress, if watered before reaching the permanent wilting point.

Flooding: Flooding for longer periods is toxic to nearly all plants. In flooding, the damage results from the exclusion of oxygen from the root zone soil. Injurious effects are caused by several metabolic imbalances including insufficient absorption of mineral salts, especially nitrogen, leaf wilting accompanied by slower photosynthesis and the accumulation of toxins caused by microbes around the roots.

Water-logging: In water-logged soils, water fills the air spaces and thus there is a rapid reduction in oxygen level around the roots due to the very slow diffusion of the gas through water. This reduced supply of oxygen adversely influences the respiration, metabolism and ultimately drying of trees.

Soil salinity/sodicity: A common and important stress in certain areas is the presence of high salt concentration in the soil. Millions of acres have gone out of production due to the soil salinity/sodicity (Khan, 1993). A tree faces two problems in such areas, one of obtaining water from a soil of negative osmotic potential and another of dealing with the high concentration of potentially toxic like sodium, carbonate and chloride ions. Still another potential problem for plants growing on saline sodic soils is obtaining enough potassium (K^+). This is because Na^+ compete with the uptake of K^+ by a low affinity mechanism and K^+ is commonly present in such soils in much lower concentrations than Na^+.

High temperature: Due to the greenhouse effect or global warming, the relative temperatures of different places are gradually increasing in different parts of the world including Pakistan. Our soils are already low in organic matter content i.e., with less than 1%. Now due to the increasing temperature, this amount is further decreasing, thus making the soil compact, less porous and ill-aerated. This deteriorating soil condition in turn is greatly affecting the root respiration in trees.

Insecticides: Most of the chlorinated, phosphatic and carbamate insecticides kill the soil microarthropods, i.e., springtails (Collembola) and saprophagous mites (Acarina), and pauropods, which normally feed on fungi, nematodes and bacteria in the soil. When numbers of microarthropods and pauropods are reduced by the application of insecticides, the populations of fungi, nematodes and bacteria are increased quickly to decompose and destroy the roots of trees.

These microarthropods and pauropods also break down the leaf-litter or plant debris into the organic matter, which makes the soil porous and well-aerated. When these organisms are killed by the insecticides, the soil shows low amount of organic matter and becomes non-porous and compact resulting in poor respiration of roots. Such soils are also deficient in plant nutrients.

On the other side, all these groups of insecticides have absolutely no effect on soil fungi, nematodes and bacteria, but rather increase their numbers. Only some organophosphates and carbamates slightly reduced their numbers, but at very high doses.

The above claims are confirmed when an abandoned corn field was treated with soil application of diazinon at 14 lb/a, there was a depression in the population of soil microarthropods (Malone *et al.*, 1967). When the microarthropods were eliminated by naphthalene fumigation, the break down of leaf-litter was reduced by 25 % (Witcamp and Crossley, 1966). The non-persistent soil insecticides, such as phorate and carbaryl, slowed the leaf-litter break down by 15% through their suppressive effect on Collembola and *Saprophagous acarina* (Way and Scopes, 1968; Barrett, 1968). An application of the organochlorine telodrin to a pasture at 2 lb/a for grub control reduced the microarthropod fauna so, severely that the undecomposed plant debris formed a thick layer on the soil surface and the underlying soil became non-porous and compact (Kelsey and Arlidge, 1968). When the organochlorine insecticides, such as DDT, BHC and chlordane, were applied to pome orchards, the microarthropod population was greatly decreased in the soil (Gould and Hamstead, 1951). Collembola in soil are highly susceptible to organophosphate compounds like zinophos, phorate and dyfonate and to carbamates such as methomyl and aldicarb and not to organochlorines (Thompson and Gore, 1972). BHC (HCH) applied to pasture at 13 kg ha^{-1} reduced the Collembola population by two-thirds and mites by one-third (Sheals, 1957). Applied at 4 kg ha^{-1}, BHC decreased the phytophagous microarthropods in the soil (Grigoreva, 1952). Lindane applied to potato fields at 2.5 kg ha^{-1} reduced certain species of Collembola and Acarina up to three years (Karg, 1961). The cyclodiene insecticides reduced Collembola and mites alike in the soil (Edwards, 1969). Aldrin tilled into the soil at 4 - 6 lb/a reduced the populations of all micro-arthropods (Edwards *et al.*, 1967). Heptachlor applied to arable

land at 2 - 4 lb/a caused similar reductions of the springtails and mites (Edwards, 1965). Endrin at 4 - 8 lb/a applied in soil had a similar reducing effect on springtails and mites (Edwards and Thompson, 1973). Parathion treatment of citrus orchards resulted in the disappearance of 10 of the 28 species of mites previously present (Olivier and Ryke, 1969). Of the systemic organophosphate insecticides, disulfoton (Disyston) applied in granules at 2 lb/a in a cotton field furrows to control aphids resulted in 95 % reduction of Collembola and mites (Abdellatif and Reynolds, 1967). Phorate and demeton reduced springtail populations when applied at 1 lb/a in contrast to diazinon or malathion, where the reduction occurred only when dosages reached 25 lb/a (Way and Scopes, 1968). Carbaryl applied to a forest stand for the control of gypsy moth at 10 lb/a reduced the floor populations of Collembola and mites by 90 %, the reduction was 50 % at 1.25 lb/a (Stegeman, 1964). Aldicarb at 10 lb/a reduced Collembola and mites by 60 % (Edwards and Lofty, 1971). Reductions in the numbers of minute pauropoda, which feed on fungi and plant debris in the soil, were observed after treatments with DDT at 10 lb/a (Edwards *et al.*, 1967), with chlordane at 2 lb/a (Long *et al.*, 1967) and severe reductions with aldrin at 4 lb/a (Edwards *et al.*, 1967). Parathion, diazinon and disulfoton applied at 8 lb/a or phorate and chlorfenvinphos at 4 lb/a virtually eliminated the population of pauropods in the soil.
Earthworms are present in large numbers in the soil (about 2000 in 1 m^2). They burrow in soil and thus improve the soil aeration and drainage, which are necessary for better root respiration. Different insecticides severely kill the earthworms resulting in poor respiration of roots, as seen in the following lines.
Application of DDT at 25 lb/a showed a reduction of 85 % in surface castings of earthworms (Doane, 1962). Aldrin at 15 lb/a could be used for controlling earthworms in turf (Legg, 1968). Dieldrin applied to cropland at 15 lb/a completely controlled earthworms (Legg, 1968). Chlordane is toxic to earthworms and its application at 2 lb/a in sugarcane fields suppressed earthworms by 90% (Long *et al.*, 1967) and at 18 lb/a it afforded complete control of earthworms in sports turf (Doane, 1962). Heptachlor applied at 1.25 lb/a to crop land for fire ant control reduced earthworm population by 25% (Rhoades, 1962 and 1963). Toxaphene at a higher dose of 8 lb/a reduced the earthworms in turf (Legg, 1968). Phorate and fensulfothion at 3 - 4 lb/a caused heavy initial kills (80-90%) of earthworms (Edwards and Thompson, 1969). Carbaryl at 2 - 4 lb/a reduced the pasture populations of earthworms by 60% (Edwards and Thompson, 1969). Carbofuran at 4 lb/a caused 95% reduction in pasture populations of earthworms (Thompson, 1970).

Herbicides: Most of the herbicides don't kill the insects and mites directly, but reduce their numbers by reducing the vegetation cover on the soil surface. Only some herbicides, namely simazine, DNOC and possibly atrazine have a direct lethal effect on springtails and mites. Similarly, only a few herbicides are directly toxic to earthworms, while others have virtually no effect as seen from the present review.
Simazine applied at 2 - 4 lb/a reduced the total numbers of springtails and mites by 13 - 50% (Edwards, 1964). When barley fields were treated with MCPA or MCPB herbicides, one-half of the Collembola were killed (Southwood and Cross, 1969). DNOC treatment at 6 kg ha^{-1} applied to winter rye resulted in 50% reduction of Collembola and mites in the soil (Karg, 1964). DNOC at 5 kg ha^{-1} to a loam soil reduced 12% population of springtails (Bieringer, 1968). When dalapon at 17 kg ha^{-1} and paraguat at 11 kg ha^{-1} were applied to clear turf, the populations of collembola and mites were greatly reduced (Curry, 1970). Applied to grassland, atrazine and monuron herbicides proved fatal and caused reduction of the earthworm population (Fox, 1964). Application of propham at 3.4 lb/a, chlorpropham at 1.8 lb/a or DNOC at 3.6 lb/a caused 30-40% mortality of some earthworms (van der Drift, 1963).

Fungicides: Foliar application of fungicides is safer, but the seed treatment and soil application are toxic and hazardous for springtails (Collembola), mites (Acarina) and earthworms.
Some fumigant fungicides like methyl bromide are extremely lethal to the populations of springtails and mites in the treated soil (Edwards and Thompson, 1973). The soil fumigant dazomet applied at 325 lb/a strongly reduced the populations of Collembola and oribatid mites (Edwards and Lofty, 1971). Methyl bromide, dazomet, metham and chloropicrin proved toxic to earthworms in the soil (Edwards and Lofty, 1971). Use of copper fungicides at 2000 ppm in orchards resulted in the disappearance of earthworms (Mellanby, 1967). The systemic fungicides, such as benomyl, thiophamate methyl, MBC and thiabendazole at 0.25 lb/a proved toxic to earthworms (Stringer and Wright, 1973). Pastures sprayed with benomyl at 7 lb/a showed 95% reduction in numbers and 91% in biomass of the earthworms (Tomlin and Gore, 1974).
The above environmental stresses disturb the organismal balance in the soil. They cause reduction in the population of soil microarthropods, such as springtails, mites and pauropods, which feed on different types of fungi, nematodes and bacteria. As a result of this reduction in the numbers of microarthropods, the populations of different fungi, nematodes and bacteria greatly increase, resulting in more attacks and faster decay of tree roots over large areas. The environmental stresses also cause reduction in the amount of organic matter in the soil. Due to this reduction of organic matter, the soils are becoming compact, less porous and poorly aerated with the passage of time. This deteriorated physical condition of the soil has resulted in the poor respiration of roots with their ultimate decay. It may be pointed out that insects attacking the roots and aerial parts of trees don't play any role in drying the trees.
High populations of the fungi, such as *Fusarium solani*, *phytophthora* sp. and *Ganoderma lucidum*, and nematodes belonging to different genera have been recorded and identified from the affected roots. In most cases, the primary injuries to roots are caused by the nematodes and then they are attacked by the fungi present in the soil. These fungi plug the xylem vessels of roots with their mycelial growth and cause decay of roots, which are unable to supply water and salts to the trees for manufacture of their food. The decay of roots is further assisted by the poor respiration (aeration) of roots. As a result, the trees dry up.

Treatment: For the purpose of control, the upper roots of the trees to be treated were exposed by excavating the soil in a 3-4 feet wide circular ditch around the tree stems. A wider ditch in case of larger trees and a narrower ditch in smaller trees was dug out starting right from the stem of trees. While exposing the roots, care was taken not to cut the thin feeding or absorbing roots. The exposed roots were left as such for 8-10 days for aeration. Then, the common salt at the rate of 1 - 2 kg per tree (depending upon the size of tree and ditch) was dusted in the ditch, which thereafter was almost filled with water so that the salt could be absorbed deep into the soil. When the water and salt were absorbed by the soil, the ditch was again filled with water and half a liter of commercial formalin (38%) was applied on water. Immediately after this, the rotten leaf-litter manure (compost) was thrown in water in such a quantity that it almost filled the ditch. If the formalin is not immediately covered with compost from above, it will quickly evaporate in the air and will soon be wasted. Finally, a layer of the excavated soil was applied on the manure to completely cover it. After a few days, 1 or 2 watering were applied to the treated trees. This treatment was applied during mid December of 1999. In March, they sprouted earlier and more than the normal trees and became lush green. In subsequent years, this treatment has been tested on a large number of drying trees. All of them recovered to normal, showing 100% success of the treatment. The success of the treatment lies in the following roles of its component parts:

(a) The formalin vapours penetrate into the soil and kill various fungi, nematodes and insects present in it.
(b) The common salt absorbed in the soil assists formalin in killing different fungi and also protects the roots from their future attacks.
(C) The rotten leaf-litter manure adds organic matter in the soil and besides supplying nutrients keeps it porous for aeration of the roots.

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