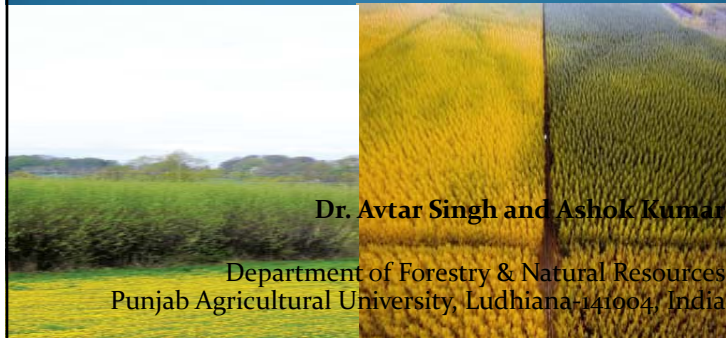


## ECOFRIENDLY RESTORATION OF PROBLEMATIC SOIL THROUGH WILLOW AND POPLAR SPECIES



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## INTRODUCTION

- Salicaceae family
- Principally used for environmental purposes, including soil and water protection, providing valuable services.
- United States poplar plantations for wastewater treatment.
- China, poplars for shelterbelts and sand dune stabilization.
- United Kingdom, they provide shelter and ground cover for free-range chickens.
- Bulgaria and Chile, willows planted along river banks to stabilize them and reduce sedimentation.

### • Uses

- Biomass production
- Minimization the negative impacts on environment on local ecosystems.
- Providing a cost-effective material for reclamation of disturbed landscapes
- Stabilizing ecosystem
- Phytoremediation



### Ecosystem restoration

- Current environmental policy of “no net loss,” based on mitigation of damaged and destroyed natural sites with sites of equivalent ecological complexity is aimed at habitat replacement, enhancement of downstream surface water quality, and decreased risk of flooding  
(Mitsch *et al.*, 1998)
- Willow and poplar are an effective ecological restoration, in both structure and function and commonly installed in riparian restoration programs as a “nurse crop” for the establishment of larger and longer-lived woody species.
- The perennial habit of willows confers larger amount of litter and increased humus content in the soil, efficiency of nutrient uptake over a longer growing season, better root penetration into the soil, and higher water use  
(Ledin, 1998)
- Poplar used for restoring arid ecosystem through reducing wind waves

## Ecosystem restoration



### Waterlogged area-Willow

- Waterlogging and burial by sediments have stronger effects such properties which results in the creation of bare substrates that are highly favorable for the establishment of Salicaceae (Schnitzler, 1995).
- Willow has excellent capacity for acquiring nutrients under a variety of conditions and for tolerating waterlogging (Nixon *et al.*, 2001).
- Ability to recommence growth after inundation the production of adventitious roots in order to deal with soil anoxia and high uprooting resistance (Vandersande *et al.*, 2001)



Willow in waterlogged area



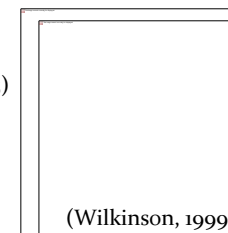
### Waterlogged area-Poplar

- Poplar clones showed remarkable tolerance to flooded soil and less mortality
- Greatest damage from flooding usually occurs during the growing season and dormant season flooding has little effect (kozlowski 1982)
- Clones show high resistance to waterlogged soil such as Tacamahaca clones Fritz Pauley, Androscoggin, clone 36-134, clone 327-1 showed extreme root and shoot growth in waterlogged soil. (Fillion *et al* 2009)



### Water eroded areas-Willow

- Often planted to stabilize riverbanks, lakes, ponds, manmade drainages and channels that are subject to frequent flooding (Lefkowitz, 2002)
- Controlling water erosion on the peat soils with high groundwater tables (Morgan, 1995)
- Efficient protection against wave erosion in reservoirs, stabilizing and naturalizing areas of bare mud (Morgan and Rickson, 1995)
- Fine fibrous roots of willow is more effective in erosion control than the large rope like root system of some poplar



(Wilkinson, 1999)

### Water eroded areas-Poplar

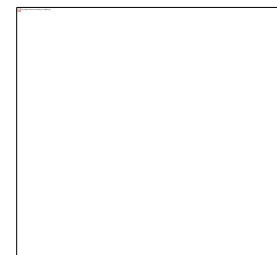
- Using stem cutting seedling provides fine fibrous roots which helps in controlling water erosion
- Poplar play a major role in erosion control in New Zealand where transformation of forests into grassland coupled with burning and overgrazing caused increased runoff and accelerated erosion on steep and erodible slopes of hill country



(Wilkinson, 1999).

### Rehabilitation of Sandy lands

- Stabilization of sand dunes and other unstable surfaces can be achieved by planting tolerant *Salix* species due to fibrous root system (Schiechtl, 1980).
- In Germany willows are used for erosion control on sand hills along highways (Schiffer, 1999)
- In China, *P. simonii* has been extremely successfully used for the reforestation of large areas of desert, in spite of severe winters with heavy snow and hot dry summers with searing temperatures in excess of 40 degrees as well as continuous strong winds (Treeco, 2010).



### Reclamation of industrial sites

- Many authors sight *Salix* among other woody plants as tolerating urban conditions (Schmidt, 1992)
- Resistance of some willow species to soil compaction and salinity can be exploited by its planting in urban naturalized areas bringing indigenous plant material into the urban environment. (Hightshoe, 1998)
- Two hybrid poplar clones (*P. deltoides* × *P. maximowiczii*—clone Eridano and *P. euramericana*—clone I-214) responded to industrial waste treatment through increasing plant growth and metal accumulation indigenous plant material into the urban environment (Sebastiani, 2004)
- Deep row placement of biosolids for reclamation of coal mines with hybrid poplar plantation has been successful in first two growing season (Toffey, 2008).

### Land reclamation

- Fast stabilization of chemically degraded land surfaces and reestablishment of a biologically active soil surface can be achieved using *Salix* species
- *Salix* species are able to establish on waste grounds and badly degraded soils with scarce topsoil, such as industrial spoils, mines and gravel pits, spoil-heaps of lignite mines, overburdens, quarries, highly eroded soils, waste sites and roadsides (Bungart and Huttel, 2001)
- *Salix* has been reported to have tolerance to at least four (Cd, Cu, Zn, Pb) and to one (Cesium) of four radionuclides (Punshon and Dickinson, 1997).



### Types of Phytoremediation Systems

Treatment Method	Mechanism	Media
Rhizofiltration	Uptake of metals in plant roots	surface water and water pumped through troughs
Phytotransformation	Plant uptake and degradation of organics	Plant uptake and degradation of organics
Phytoextraction	Uptake and concentration of metals via direct uptake into plant tissue with subsequent removal of the plants	soils
Phytostabilization	Root exudates cause metals to precipitate and become less bio available	soils, groundwater, mine tailings
Phytovolatilization	Plant evapotranspires selenium, mercury, and volatile organics	soils, groundwater

### Phytoextraction- Willow

- Resistance of willows to some metals (Cd, Cu, Zn, Ni, Pb, and Fe) and its ability to accumulate significant amounts of metal in plant tissues had been documented and suggested its possible use for metal extraction  
(Kuzovkina et al., 2004b)
- Profitable biomass production is an additional advantage of *Salix* over the herbaceous species, providing the farmer with an additional income during the restoration time  
(Eriksson and Ledin, 1999)
- Inherited differences in lipid peroxidation and enzymes' level against high metal levels are a possible explanation for the metal tolerance of some clones  
(Landberg and Greger, 2002)

### Phytoextraction- Poplar

- Poplar is now increasingly planted along effluent drain channels as a means for phyto-remediation.
- Low sulfate concentrations in Punjab soils allowed the plants to accumulate high concentrations of Se.  
(Banuelos and Dhillon (2011)
- Treatment comprising fly ash at 10% (v/v), farmyard manure at 20% (v/v) and microbial consortium of *Pseudomonas striata* [*Pseudomonas putida*] and *Azotobacter* sp. at 30 ml/pot promoted the growth of *P. deltoides* in nursery  
(Aggarwal and Goyal, 2009).

### Phytodegradation

- Willows' ability to transport oxygen down to the root zone through aerenchyma formation may contribute to providing better conditions for bacterial growth
- Prairie Cascade willow (*Salix* x 'Prairie Cascade') has shown vigorous growth on blackened soil produced by an oil spill and capability of cleaning the soil via stimulation of oil-degrading microbes associated with their roots.  
(Thompson, 1998)
- Poplar hybrids have ability to both accumulate and tolerate ions such as Se or B under saline conditions is useful for agroforestry drainage water reuse programs in central California  
(Banuelos, 1999)



### Phytostabilization

- Dense root system, penetrating deep into the soil, high transpiration rates providing efficient control of soil water and high filtering capacity for pollutants, along with continuous growth of some species during the whole growing season, increase willows' metabolic potential and create an efficient dehydration plant while locking up the pollutants.
- Willows' ability to sequester heavy metals and other contaminants in their root systems, halting their circulation within the environment
- hybrid poplar clones Crandon (*Populus alba* x *grandidentata*), Nisqually-1 (*P. trichocarpa*), D.Pa (*P. alba*) and willow clone S365 (*Salix discolor*) had the highest mass gain and best health at the highest TCE concentration

(Ettala, 1988)

(Rachel *et al.*, 2011)

### Conservation of hilly areas

- Strategic planting of poplar and willow trees can significantly reduce the degree and severity of slippage, earth flow movement and gully scouring.
- Douglas *et al.* (2011) reported that spaced conservation trees of various sizes on slopes of mostly 25-30° reduced the extent of soil slippage at 65 sites by an average of 95% compared with slippage on nearby pasture control sites.
- Once slippage has occurred on a pastoral slope recovery of production is unlikely to improve beyond 80% of the uneroded slope (Rosser and Ross 2011).

Laboratory testing found that the tensile strength of poplar and willow roots collected from 1 year-old trees ranged from 36.3 to 45.6 MPa

(Hathaway and Penny 1975)

- During 2011, a number of 30 stands/populations with Romanian poplar and willow species with a surface of 113.9 ha were identified phenotypically evaluated and "in situ" conserved

(Romania country report 2011)



### Willow and Poplar for erosion control on pastoral hill areas

- Gully planting
- Shallow slip planting
- Earth flow planting

