Bio-control Measures to Manage Soil and Water Salinity for Sustainable Agriculture

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ABSTRACT

The waterlogged and saline soils are found all over the country. About 9.03 M ha of land is affected by salinity and alkalinity problem in India. Due to improper management of water in agriculture, the area under problematic soils increasing every decade. Inorder to meet food security of nation on sustained basis, both salt affected soils and waters need to be managed using appropriate techniques. These techniques employ mechanical, chemical and bio-control measures. Bio-control measures involve selection of more salt-tolerant crops, residue management, and bio-drainage. Sugar beet, sugar cane, dates, cotton and barley are among the most salt tolerant crops. Crop residues left on the soil surface reduce evaporation. Thus, less salt will accumulate towards soil surface and thereby managing salinity. The bio-drainage concept is based on utilizing the consumptive water use of plants with aim to remove excess groundwater through the process of transpiration by salt tolerant vegetation and thereby reducing problem of salinity. This is achieved by enhancing the transpiration capacity of the area by introducing high-water use vegetation in large areas to maintain groundwater balances below the root zone of the crops. Therefore, bio-control could be utilized to manage soil and water salinity for sustainable agriculture.

Key words: *Soil salinity, salt tolerance, residue management, bio-drainage, bio-control measures*

INTRODUCTION

The problems of water logging and soil salinity are common world over. About 10-50% of the irrigated lands in various countries have been affected and 1.5 million hectare (M ha) area is lost annually due to these problems. The waterlogged saline soils are found all over the country. About 9.03 M ha of land is affected by salinity and alkalinity problem in India, which reduce agricultural productivity. About 8.5 M ha area has been waterlogged and 5.5 M ha affected by salinity in the country. The irrigation development expected sustained benefits in the country, but big constraint is the problems of waterlogging and salinity development over large irrigated areas. Salinity from irrigation can occur over time since almost all water even natural rainfall contains some dissolved salts (ILRI, 1989). At the same time agriculture is facing increase in water demand at 2.4% annually during 2005 -2030 as well as reducing share of water due to competing demand from industry and urbanizations. Therefore, to fulfill food and nutritional security of nation on sustained basis, both salt affected soils and waters need to be managed using appropriate techniques.

Severity of Problem

Water logging and salt problem have been experienced in irrigation projects all over the country. The examples are Chambal Command areas in Rajasthan and M.P., Indira Gandhi Canal Project in western Rajasthan, Kosi and Gandak Project Commands in Bihar, the Tungabhadra Project area in Karnataka, the Nagarjunasagar Project area in Andhra Pradesh and the Kakrapar Project area in Gujarat. Construction of drainage canals, field drains and avoiding wastage of canal supplies have been adopted as remedial measures. However, lack of maintenance, operational constraints of large irrigation projects, and construction of highways, railway embankments and other obstructions, without providing for adequate drainage facility are still the major factors for water logging (Singh et al., 2011). In the Chambal Command area soils became water logged with a few years of introduction of irrigation. In many coastal areas excessive groundwater exploitation has caused seawater intrusion, worsening the salinity problem. The status of water-logging and soil salinization problems in irrigation command area and country as a whole as estimated by MOWR, Working Group (1991) is presented in Table 1. Extent of waterlogged and salt affected areas for some states in India (Tyagi, 1999) has been presented in Table 2.

Table 1: Water logged and Salt affected areas in million hectares

Source	Irrigated Command Area			
	Water logged	Salt affected		Total
		Saline	Alkali	
MoWR (1991)	2.46 (8.53)	3.06 (5.50)	0.24 (3.58)	5.76 (17.61)

Note: Values in parenthesis are by MoA, GoI country as a whole.

Excessive soil salinity affects the soil structure and can reduce crop yields. High concentrations of salt in the soil can result in a physiological drought condition. That is, even though the field appears to have plenty of moisture, the plants wilt because the roots are unable to absorb the water. Thus, salinity control of irrigated land is necessary to prevent yield reductions where saline water is used for irrigation or where saline shallow water tables exist. This paper discusses bio-control techniques for addressing the issues of salinity management for sustainable agriculture

Sustainable Management of Salinity

The salinity problems adversely affect the targets of food production and reduced efficiency of capital investment in irrigated agriculture as well as have become an environmental concern. Sustainable agriculture could be achieved if its all components, viz. environment, society and economy remain in balance (Ott, 2003 and Adams, 2006). Adequate drainage is required to improve soil health and soil water plant interaction for enhanced water productivity to ensure sustainability (Singh et al, 2009 and Rao et al., 2009).

Techniques for controlling salinity require more frequent irrigations, selection of more salt-tolerant crops, pre-plant irrigation, bed forming and seed

Table 2: Geographical, waterlogged and salt affected areas (mha) of some states in India

State	Geographical area	Waterlogged area	Salt affected area
A.P.	27.44	0.339	0.813
Bihar	17.40	0.363	0.400
Gujarat	19.60	0.484	0.455
Haryana	4.22	0.275	0.455
Karnataka	19.20	0.036	0.404
Kerala	3.89	0.012	0.026
M.P.	44.20	0.057	0.242
Maharashtra	30.75	0.111	0.534
Orissa	15.54	0.196	0.400
Punjab	5.04	0.199	0.520
Rajasthan	28.79	0.348	1.122
Tamilnadu	12.96	0.128	0.340
U.P. & Uttaranchal	29.40	1.980	1.295
Total	258.43	4.528	7.006

placement. Alternatives that require significant changes in management are changing the irrigation method, altering the water supply, land-leveling and modifying the soil profile. Soil salinity control involves water table control and flushing in combination with tile drainage or another form of subsurface drainage (Abrol et al., 1988; and Bureau of Reclamation, 1993). Many studies have revealed that saline soils can be used successfully for crop growth without long-term hazardous effects on crops and soils if proper practices such as adoption of furrow irrigation on salt leaching, selecting appropriately salt-tolerant crops, and artificial subsurface drainage (*Oosterbaan* 1990; *Rao et al*. 1990; Moreno et al., 1995; Hanson and May, 2004; Hanson et al., 2006; Roberts et al., 2008) are established. The salinity management techniques require either or combination of mechanical, chemical and bio-control measures.

Bio-Control Measure

There is a wide range in plant species with respect to response to salinity which could be used to control salinity. The properties of residue to reduce the evaporation could be utilized to reduce salt accumulation. Problem of salinity could also be managed utilizing the principle that excess groundwater may be removed through the transpiration by vegetation in the area. Bio-control measures may involve selection of more salt-tolerant crops, residue management, and bio-drainage.

Salt tolerant crops: In general, salinity decreases both yield and quality in crops. Many crop species and varieties have been identified as salt tolerances (Mass and Grieves, 1987; Maas, 1990). Sugar beet, sugar cane, dates, cotton and barley are among the most salt tolerant; whereas beans, carrots, onions, strawberries and almonds are considered sensitive (Maas, 1986). However, as salinity increases beyond some threshold tolerance, yield decline is inevitable. When salt concentrations in the soil water reach toxic levels, leaves or shoots may exhibit visible symptoms of tip or edge burning or scorching due to high internal concentrations of salts. Other visible symptoms may be associated with nutrient imbalances caused by competitive interactions between Na^+ and Ca^{2+} or K^{4+}, or between Cl^- and nitrate (Grattan and Grieve, 1992). Depending upon crop species and salinity concentration, salt in the crop root zone may also influence the rate of plant development by increasing or decreasing the time to crop maturity (Shannon et al., 1994).

In some crops, salinity changes plant growth habit or increases succulence (Luttge and Smith, 1984; Shannon *et al.,* 1994). Many crops have little tolerance for salinity during seed germination, but significant tolerance during later growth stages. Some crops such as barley, wheat and corn are known to be more sensitive to salinity during the early growth period than during germination and later growth periods. Sugar beat and safflower are relatively more sensitive during germination, while the tolerance of soybeans may increase or decrease during different growth periods depending on the varieties.

Salinity could be categorized from non- saline to very strongly saline (Table 3) for the purpose of crop selection for saline soils. At relatively low salinity, especially among crop species such as cotton or the halophytic sugar beet, some salinity may actually improve crop production. This effect has been attributed in some instances to an improvement in water use efficiency of the plant (Letey, 1993). High levels of soil salinity can be tolerated if salt-tolerant plants are grown. Sensitive crops lose their vigor in slightly saline soils, most crops are negatively affected in moderately saline soils, and only salinity resistant crops thrive in severely saline soils (Blaylock, 1994).

Table 3: Salinity rating and electrical conductivity, deci-Siemens per metre (dS/m)

Soil Depth (cm)	NS	WS	MS	SS	VSS
0-60	<2	2-4	4-8	8-16	>16
60-120	<4	4-8	8-16	16-24	>24

Note: NS: Non Saline; WS: Weakly Saline; MS: Moderately Saline; SS: Strongly saline;

VSS: Very Strongly Saline

There is potential yield reduction with increasing salinity of soils for field and vegetable crops (Table 4). Soil salinity levels and yield potential of salt-tolerance classes of horticultural and landscape plants indicate 100% loss of relative growth or yield at 8, 16, 24 at 32 dS/m for sensitive, moderately sensitive, moderately tolerant and tolerant crops, respectively (Blaylock. 1994). Yields of most crops are not significantly affected where salt levels are 0 to 2 dS/m. Generally, a level of 2 to 4 dS/m affects some crops. Levels of 4 to 5 dS/m affect many crops and above 8 dS/m affect all but the very tolerant crops (Cardon et al., 2011).

Residue management: The exposed soils have higher evaporation rates than those covered by residues. Residues left on the soil surface reduce evaporation. Thus, less salt will accumulate and rainfall will be more effective in providing for leaching. Evaporation and resulting salt accumulation, tends to be greater in bare soils. Fields need to have 30 to 50 percent residue cover to significantly reduce evaporation. Under crop residue, soils remain wetter, allowing fall or winter precipitation to be more effective in leaching salts, particularly from the surface soil layers where damage to crop seedlings is most likely to occur. Plastic mulches used with drip irrigation reduce salt concentration from evaporation. Sub-surface drip irrigation pushes salts to the edge of the soil wetting front, reducing harmful effects on seedlings and plant roots.

Table 4: Potential yield reduction from saline soils for selected crops

	Relative yield decrease (%)			
	0	**10**	**25**	**50**
	(ECe, dS/m)			
Field crops				
Barley	8.0	10.0	13.0	18.0
Wheat	6.0	7.4	9.5	13.0
Sorghum	4.0	5.1	7.2	11.0
Soybean	5.0	5.5	6.2	7.5
Vegetables				
Broccoli	2.8	3.9	5.5	8.2
Cucumber	2.5	3.3	4.4	6.3
Spinach	2.0	3.3	5.3	8.6
Cabbage	1.8	2.8	4.4	7.0
Potato	1.7	2.5	3.8	5.9

Bio-drainage: Salt balance is one of the most important issues addressed by bio-drainage. The aim of bio-drainage is to remove excess groundwater through the process of transpiration by vegetation and thereby reducing problem of salinity. This is achieved by enhancing the transpiration capacity of the land by introducing high-water use vegetation types in large areas to balance recharge and discharge processes to maintain groundwater balances below the root zone of the agriculture crops. The rates of transpiration and groundwater uptake by trees underlain by relatively shallow (5-8 m below surface) water tables, were very high, exceeding the annual evaporation from pasture by a factor 3-6 (1200-2300 mm/yr) (Greenwood *et al.* 1985). Bio-drainage crops need to be salt tolerant. The water use capacity of trees and other crops decreases with increase in water salinity.

The *Eucalyptus* species are suitable for biodrainage. Other suitable species for biodrainage may be *Casuarina glauca, Terminalia arjuna, Pongamia pinnata* and *Syzygium cuminii,* etc. In the case of Eucalypt species, it reduces to about one-half of potential when the water salinity increases to about 8 dS/m (Oster *et al.* 1999). In high-salinity environments plant salt uptake might be negligible in relation to the salts present in the system, under low-salinity scenarios salt balance by plant uptake and removal might be achievable (Heupermanet et al., 2002).

Properly designed parallel strip plantations of *E. tereticornis* should be raised on farmers' field and in block plantation along canals for the uniform reclamation of waterlogged areas of semi-arid regions having alluvial sandy loam soils in Haryan, India. These plantations also be raised on potentially waterlogged areas to prevent their conversion into waterlogged areas (Jeet, et al., 2008). Bio-drainage may be attributed to reclamation of waterlogged area, controlling of water table, providing shelter belts, provide additional wood and forest products, biodiversity, and limited salinity control. It is having limitation that a relatively large area of land requirement at about 10% of irrigated area is required.

CONCLUSIONS

Bio-drainage removes excess groundwater through the process of transpiration by vegetation and thereby reducing problem of salinity. The plantation of some species suitable for bio-drainage are *Eucalyptus, Casuarina glauca, Terminalia arjuna, Pongamia pinnata* and *Syzygium cuminii, E. tereticornis*. These plantations may also be raised on potentially waterlogged areas to prevent their conversion into waterlogged areas. Bio-drainage may be attributed to reclamation of waterlogged area, controlling of water table, providing shelter belts, provide additional wood and forest products, and biodiversity. Therefore, bio-control measures could be utilized to manage soil and water salinity for sustainable agriculture.

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