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Title: Salt in the soil environment, and its consequences for the management of Chickpea and Pigeonpea

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J. S. KANWAR

--A-- Salt in the Soil Environment, and its Consequences for the Management of Chickpea and Pigeonpea

--C-- K.L. Sahrawat and J.R. Burford

--C--Abstract

Chickpea and pigeonpea are well adapted to the harsh and nutrient deficient environment in the semi-arid tropics (SAT), but have only moderate tolerance to salinity. Growth and yield of these crops on salt affected soils in the SAT is affected by the interactions between their hardiness to the SAT environment and their moderate tolerance to salts. The extent and types of salt affected soils in South and South-east Asia and their amelioration are briefly discussed. However, the cost:benefit ratio for amelioration is generally unfavourable for dryland agriculture.

--B--Introduction

Chickpea and pigeonpea are hardy crops which have adapted well to the harshness of the semi-arid tropical (SAT) environment. One example of their hardiness and adaptation is their ability to grow and mature in low-P status SAT soils, without the need for P inputs, when other crops such as sorghum and millet require moderate inputs (ICRISAT 1981). Another example is their ability to grow well in low-rainfall environments, provided that the soil has a high available soil moisture

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storage capacity. However, both crops appear to have only a moderate tolerance to salinity (Chapters 1, 2; Chapters 1, 1). We can therefore expect interactions between the moderate salt-tolerance of these two crops and their hardiness in other respects. But to consider these interactions, we first need to know the types and extent of salt-affected soils in South and South-east Asia.

In this region -- South and South-east Asia -- Ponnamperuma and Bandyopadhya (1980) estimated that an area of about 67 m ha is mildly- to moderately-affected with salt-related problems. The majority of these problem soils are saline (49 m ha). The remainder are alkali-soils (12 m ha), or acid-sulphate soils (5 m ha). To define these categories, saline soils are those soils containing sufficient salts to reduce the growth of plants. Soils in the other two groups may not have a high salt content now but the effects of the original composition of the salts persist in the soil. In alkali soils, the dominant cation is sodium, and the presence of carbonates and bicarbonates raises the pH to extremely high levels. Acid-sulphate soils are usually found after the intrusion of sea-water; the reduction of sulphate causes extremely low soil reactions, resulting in high concentrations of ionic forms of iron and aluminium in the soil.

Within the South and South-east Asian region, the location and causes of salinity may be grouped into the following classes:

1, Low-lying coastal areas, where salt has accumulated from either periodic inundation by seawater or bra
or by upwelling of saline groundwater.

ii) Inland areas, where salt accumulation arose from

a) natural sources e.g. wind blown or rainfall-borne salt (cyclic salt), and poor drainage

b) anthropogenic causes e.g. large irrigation schemes or localized irrigation with brackish water

Saline soils of the low-lying coastal areas occur throughout the region; but, the inland saline soils are primarily located in India and Pakistan, where they extend over very substantial areas of the Indo-Gangetic plains in the former Punjab geographical area. Almost all of the alkali soils of the region are also located here. Less is known about the smaller areas of upland soils that are saline or salt-affected, despite the importance of salinity for pulse crops under rainfed conditions; it is only recently that attention has been given to the upland soils, for example as in Peninsular India (CSSRI 1979). Past salinity research has concentrated on the coastal low lying soils for paddy rice production (Ponnamperuma and Bandyopadhya 1980), and on the inland soils of the large irrigation schemes in the Indus and Ganges valleys (Kanwar 1980).

--B--Physical and chemical environment of salt-aff

Saline soils are flocculated because of t

salts in the soil solution. The salt concentr

directly as well as, indirectly, the high

uptake of water, and the different ionic solution (compared to 'normal' soils) may markedly affect the availability and uptake of nutrients by plants.

In most saline soils of this region, sodium is the dominant ion. Lowering of the salt content of the soil by leaching, either naturally by rainfall or with good quality (low salt) water does not eliminate the problems caused by salt. This is because, as the salt concentration in the soil solution is reduced, the clay will disperse only when it has a small proportion of its exchange sites occupied by sodium, e.g. less than 7-15. (Northcote 1971, USDA 1973). The low permeability of sodium-dominated soil hinders further removal of salts and also promotes waterlogging.

The formation of carbonates and bicarbonates of sodium leads to extremely high soil reactions, with pH values of 9 and 10 being not uncommon, and this adversely affects the availability of some mineral nutrients such as Fe and Zn. Where removal of salt by leaching is attempted, the use of gypsum may be essential to provide both a source of calcium to ensure calcium-dominance of the exchange cations on the clay surfaces and to provide a non-injurious salt in solution to minimize dispersion of the clay.

Similarly, in acid sulphate soils, the extremely low pH creates a very poor medium for plant growth, because of the low pH per se as well as associated high Al, Mn and Fe ion concentrations. Acid sulphate soils have variable soil physical conditions depending on [illegible] and Al and Fe salts present. However, they usually have a [illegible] condition, with poor aeration when wet or waterlogged.

--b--Management of salt-affected soils, or salinity-prone soils

Reclamation of saline-alkali soils by leaching and gypsum application leads to two major causes for concern for subsistence agriculture. First, the ameliorants involved are bulky, and large amounts are involved; unless supplies are available nearby, the costs will be high. Second, in many situations, the propensity of a soil to develop a salinity-related problem can be predicted in advance; the cure may be much more difficult than prevention because leaching for removal of salt or for changing the balance of adsorbed cations, will become much more difficult when the whole profile has become alkali affected.

A soil may have a good permeability before salinity-related problems develop. However, once an appreciable proportion of the cation-exchange sites become occupied by sodium, any attempt to leach salt through the profile will cause dispersion, and a decrease in permeability to negligible rates. For heavy-textured alkali soils, the addition of gypsum to the soil surface will cause improved permeability only in the surface layer. Deep leaching through the profile will be prevented by sodium clay at depth; but, calcium in gypsum can readily replace that sodium only with adequate through leaching. Clearly, the best solution is to prevent the development of sodium-affected clays throughout the profile; ideally, gypsum should be added as soon as a potential saline-alkali problem is recognized and before the problems become severe.

Provision of drainage systems will be nec
soils for removal of water and salt from depth.
the better textured soils, e.g. the Entis[illegible]

plain, are the costs of provision of drainage likely to be economic. On these, widely-spaced tube wells to pump any water will be adequate. On the heavier textured soils, however, the solution is much less palatable; the poor lateral drainage in these soils means that closely-spaced tile-drains may be essential for reclamation. Such drainage costs are extremely high, and the best solution is to concentrate on minimizing the further development of salt problems on these soils.

The costs of attempting any amelioration of soil under rainfed agriculture will be much higher than under irrigation. Restoration of the soil, with adequate availability of water, will depend on the soil's permeability. However, under rainfed agriculture, only a small proportion of natural rainfall moves through the profile, even with optimum soil permeability. With permeability restricted, leaching will be much less and the restorative process will therefore take much longer than under irrigation. Restoration of heavy-textured soils is slow under irrigated agriculture; it will be extremely slow under rainfed agriculture. Additionally, the benefits of reclamation are greater under irrigated agriculture because the potential productivity is greater than under rainfed agriculture. When these factors, viz., the speed of restoration and potential productivity, are considered the benefit:cost ratio of restoring rainfed land will be much lower than for irrigated land. Again, prevention is better [illegible]

During restoration, a gradually increasing [illegible]
becomes free from the effects of salt and alk[illegible]
influences. Plant roots can explore this [illegible]
will be deterred from deeper exploration [illegible]

environment caused by salinity at depth. Such restriction of rooting depth will effectively decrease the amount of available water in the soil that will be accessible to a crop. This consequence of the adverse environment at lower soil depths is less of a disadvantage for irrigated crops, because an increase in frequency of irrigation can compensate for the lower effective amount of available soil water. In rainfed crops, however, restriction of the volume of soil explored by roots could be a crucial factor in determining the success or failure of a crop, especially deep-rooting crops such as chickpea and medium and long-duration pigeonpea. Both crops make much of their growth in the postrainy season and depend upon full exploration of the soil profile for their water supplies. Clearly, any restriction on rooting depth, such as salinity will jeopardize the crop.

In the past, the coastal low-lying soils have been used predominantly for paddy rice; recently interest has developed in growing pulses. In other areas, especially inland soils, pulses are commonly grown under upland (non- irrigated) conditions for both soils that are commonly irrigated as well as those which are used traditionally only for rainfed agriculture. For these groups of soils, the strategy for handling salts will differ. For the irrigable soils, both coastal low lying and inland Indo-Gangetic plain, amelioration can be relatively easy. The requirements are an excess of water to flush excess salts through the soil and treatment with calcium [illegible] keep the proportion of sodium on the cation exch[illegible] the critical value above which the soil disp[illegible] inland upland soils under rainfed agriculture, e[illegible] Deccan) on which chickpea and pigeonpea are crops, amelioration is much more difficult; under natural rainfall, the rate of leaching will be much lower and the cost of calcium salts (e.g. gypsum) will be less easy for the farmer to afford because his forseeable profits are lower under rainfed compared to irrigated agriculture.

Whilst it is tempting to consider the use of salt-tolerant cultivars, these can only offer some palliative. If the soil is likely to develop a salinity problem, corrective measures must be taken; and, for rainfed crops, as early as possible because of the slowness of the restorative process once the soil has become saline.

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