GREEN MANURING: A PANACEA FOR THE RECLAMATION OF SALINE AND SODIC SOILS

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Green manuring is the ploughing under or incorporation of any green manure crops in soil while they are green or as soon as they flower. Green manures are forage or leguminous crops that are grown for their leafy materials needed for soil improvement. A green manure crop can be cut and then ploughed into the soil or simply left in the field for an extended period prior to tilling for next crop. Although only leguminous crops are considered as green manure crops, there are a few exceptions too. The growing and turning of green manure crops enriches soil organic matter vis-à-vis additional nutrients to the soil besides reclamation of saline and /or sodic soils. When incorporated into the soil, these plants break down, eventually releasing important nutrients which are necessary for adequate plant growth and development. In addition to the supply of nutrients, green manuring crops can help to scavenge the leftover nutrients from the preceding crop. It also increases soil drainage and water retention capacities that help to prevent leaching losses, soil erosion, and weed problems too as these are also incorporated.

The sustained productivity from the limited land resources is threatened by the multiplicity of resource degradation problems. Factors adding to the pressure on increasingly scarce land resources are population growth, climate change, land use changes, and environmental pollution. Mounting pressure on land resources leads to different types of degradation including development of salt affected soils. The salt affected soils alone have assumed significant global dimension as about 1000 million hectare areas in more than 100 countries are affected by this menace. India is by far no different from others with 4.71 percent of cultivable land suffering from huge economic losses due to salinity and sodicity. The use of gypsum for effective management of salt affected soils is well documented however its availability, cost and transportation are some of the serious issues that prevent small and marginal farmers from using gypsum. Green manuring is the simple, effective and cheap technology for management of these soils. The high pH, excess exchangeable Na, high calcium carbonate, low organic matter content and adverse physical properties of alkali soils influence the transformation and availability of native and applied nutrients. Nutrient release and loss mechanism of applied nutrients are also adversely affected in these soils. The crops grown in these soils invariably suffer from poor germination, crop stand, and nutritional disorders that finally results in low yields.

Figure 1: Dhaincha *in-situ* green manuring in cotton

Figure 2: Sunhemp *in-situ* green manuring in cotton

Application of green manure enhances the reclamation of saline and sodic soils by improving physical and chemical properties of

soil by markedly decreasing soil pH. Plant litter incorporation improves aggregation, aeration and water retention. Application of green biomass helps to curtail the evaporation from soil surface and thereby decreases salt concentration in the root zone profile which results in arresting sub soil sodicity. Some commonly used green manuring crops which can be very useful for reclamation of salt affected soil are given below (Table 1).

Table1 Major green manure crops and their nutrient composition on dry basis

Crops	Scientific Name	Nutrient content (%)		
		N	P	K
Gliricidia	*Gliricidia sepium*	2.76	0.28	4.60
Sunhemp	*Crotalaria juncea*	2.30	0.50	1.80
Dhaincha	*Sesbania aculeata*	3.50	0.60	1.20
Cowpea	*Vigna unguiculata*	2.13	0.25	1.51
Subabool	*Leucaena leucocephala*	2.17	0.18	1.31
Green gram	*Vigna radiata*	1.67	0.33	1.02

EFFECT OF GREEN MANURE ON SALINITY AND SODICITY

Soil salinity restricts plant growth due to high salt content which leads to creation of osmotic stress in the root zone. The application of green biomass increases the release of salts into soil solution as result of mineral dissolution due to increase in partial pressure of carbon dioxide and organic acids which leads to leaching of salts below the root zone and creates favourable environment in the root zone of crop plants. The production of organic acids (amino acid, glycine, cysteine and humic acid) during mineralization of organic materials by heterotrophs and nitrification by autotrophs cause a decrease in soil pH. The applied green manures during decomposition produce CO_2, which dissolves in water to produce carbonic acid. This acid increases the solubility of calcium carbonate minerals by lowering the pH and dissolving the calcium carbonate and forming a host of complex calcium ion pairs, thus increasing soil solution Ca^{2+} concentration which replaces Na^{+} on exchange complex and thus cause reduction in exchangeable sodium percentage (ESP). Application of green manures also reduces concentration of certain cations and anions such as Cl^{-}, SO_4^{2-}, HCO_3^{-} and CO_3^{2-}.

EFFECT OF GREEN MANURE ON SOIL PHYSICAL PROPERTIES

The extent of changes in the physical properties of sodic soils due to the incorporation of organic bio-ameliorants such as green manures is quite remarkable, which is connected with an increase in organic carbon content. In sodic soils, Na^{+} constitutes a highly dispersive agent resulting in dispersion of soil aggregates. The addition of organic matter promotes the flocculation of clay particles, which is essential for the aggregation of soil particles. The improvements in soil aggregate stability with organic bio-ameliorants and the resulting improvement in soil porosity also attribute to the presence of microbial mucilage/polysaccharides, and other exudates in rhizosphere that are adsorbed on to clay surfaces and bind soil particles into aggregates.

EFFECT OF GREEN MANURE ON SOIL ORGANIC CARBON

The green manuring improves soil organic carbon by contributing large quantity of biomass. The stabilization of aggregates can physically protect soil carbon, such that it protects mineralization of carbon associated with macro aggregates. The increased partial pressure of CO_2 from microbial decomposition of organic substrates leads to dissolution of native calcium carbonate and increase in Ca^{2+} concentration further enhance aggregation due to flocculation. The increase in aggregation, formation and stabilization of Ca-organo-clay complexes and displacement of Na from exchange sites enhances carbon storage. Also it is a fact that while the soil with non-smectitic clay mineralogy enhances added organic residue decomposition, smectitic clay soil reduces organic residue decomposition. Due to reduction in ESP the retention of SOC improves. The organic amendments also improve the SOC stock which results in better aggregation.

EFFECT OF GREEN MANURE ON BIOLOGICAL PROPERTIES

Soil biological properties are very sensitive to small changes occurring in management practices; therefore, it is possible to use them for evaluating the effects of the application of organic matter on soil characteristics. Salinization may greatly disturb a large variety of microbially mediated processes in the soil. Exogenous organic matter applications to cropland are known to improve soil biological functions, also showing positive effects in the salt-affected soils. Soil salinity can alter the organic matter turnover process, and the response pattern of C and N mineralization to salinity stress could depend on the type of organic material incorporated in to the soil. The incorporation of green manure can be an effective low-input agro-technological approach to minimize toxicity conditions induced by salinization. Amendment incorporation under high soil salinity or sodicity may also provide a buffer of pH in saline and alkaline soils, influencing the activity of microorganisms.

EFFECT OF GREEN MANURE ON AVAILABLE NUTRIENTS

The availability of nutrients in saline and sodic soils is a function of soil pH, salt content and ESP. Green manuring enhances microbial activities due to readily available food material. Green manure is broken down into plant nutrient components by heterotrophic bacteria that consume organic matter. Warmth and moisture contribute to this process, similar to creating compost fertilizer. The plant matter releases large amounts of carbon dioxide and weak acids that react with insoluble soil minerals to release beneficial nutrients. The uptake of phosphorous (P) by crops is reduced in dry-soil conditions and the availability of this macronutrient can be reduced in saline soils. Conversely, during the mineralization process, organic matter releases humic substances, which may convert soil phosphates into available forms, improving release from sparingly soluble rock minerals due to high total acidity. Soils that are high in calcium minerals, for example, can be grown with green manure to generate higher phosphate content in the soil, which in turn acts as a fertilizer. The ratio of carbon to nitrogen (C:N ratio) in a plant is a crucial factor to consider, since it will impact the nutrient content of the soil and may starve a crop of nitrogen, if the incorrect plants are used to make green manure. The ratio of carbon to nitrogen will differ from species to species, and depend upon the age of the plant. This ratio must be less than 30:1 to prevent the bacteria from depleting existing nitrogen in the soil. *Rhizobium spp*. are soil organisms that interact with leguminous green manure to fix atmospheric nitrogen in the soil. Legume, such as beans, alfalfa, clover and lupines, have root systems rich in rhizobium, often making them the preferred source of green manure material. Additionally, under saline soils the available fraction of potassium (K) can increase through the increase of CEC linked to organic matter content. Moreover, K^+ is important to maintain the turgor pressure of plant under drought and salinity stress. Green manures also contain appreciable amount of micronutrients (Fe, Mn, Zn and Cu) which when incorporated increase their status in soil. The higher increase in organic C content of soil with the application of green manures, have greater capacity to retain nutrients in forms that can easily be taken up by plants and support rich micro flora beneficial to crop's growth.

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