Management of Salt-Affected Soils for Rice Production
Rice Technology Bulletin Series

No. 1  Released Rice Varieties (1968 - 1994)
No. 2  Pagpaparami at Pagpupuro ng Binhí sa Sariling Bukid
No. 3  Paggawa ng Maligaya Rice Hull Stove
No. 4  PhilRice Micromill
No. 5  PhilRice Flourmill
No. 6  PhilRice Drumseeder
No. 7  PhilRice Rototiller
No. 8  Rice Food Products
No. 9  PhilRice-UAF Batch Dryer
No. 10 Integrated Management of the Malayan Black Bug
No. 11 SG800 Rice Stripper-Harvestser
No. 12 Dry-Seeded Rice-Based Cropping Technologies
No. 13 Maligaya Rice Hull Stove
No. 14 10 Steps in Compost Production
No. 15 Rice Tungro Virus Disease
No. 16 The Philippine Rice Seed Industry and the National Rice Seed Production Network
No. 17 10 Hakbang sa Paggawa ng Kompost
No. 18 10 nga Addang ti Panagaramid iti Kompost
No. 19 Characteristics of Popular Philippine Rice Varieties
No. 20 Rice Stem Borers in the Philippines
No. 21 Rice Food Products (revised edition)
No. 22 Leaf Color Chart (English)
No. 23 Leaf Color Chart (Ilocano)
No. 24 Leaf Color Chart (Filipino)
No. 25 Equipment for Rice Production and Processing
No. 26 Use of 40kg Certified Seeds per Hectare
No. 27 Rice Wine
No. 28 Management of Field Rats
No. 29 Controlled Irrigation: A water-saving technique for transplanted rice
No. 30 Minus-one Element Technique: Nutrient deficiency test made easy
No. 31 Management of the Rice Black Bug
No. 32 Management of Zinc-Deficient Soils
No. 33 Management Options for the Golden Apple Snail
No. 34 Use of Evaporation Suppressant
No. 35 Pagpaparami ng Purong Binhí ng Palay
No. 36 Management of Sulfur-Deficient Lowland Rice Soils
No. 37 Management of Planthoppers and Leafhoppers
No. 38 Management Options for Ricefield Weeds
No. 39 Use of Indigo as Green Manure
FOREWORD

Salinity has become a widespread constraint in rice production in most parts of the country. The extent of saline prone coastal land, which is an integral component of both the agricultural and wetland, is estimated at 0.4 M ha, of which 0.2 M are considered seriously salt-affected. Unfortunately, salt-affected areas that were cultivated for rice growing to produce only marginal yield or, in severe cases, total crop failure. Thus, proper management of these areas is necessary to increase soil productivity.

The continuing development of new and improved salt-tolerant cultivars whose parents come from a range of traditional varieties and elite lines, coupled with appropriate soil management techniques can enhance fertility and productivity of these soils. In this regard, PhilRice, in collaboration with other institutions, has been at the forefront of this continuing research and development endeavor, to provide the farmers in salt-affected areas varieties that can tolerate certain degrees of salinity. Results of this collaborative research are packaged in this bulletin to inform the readers on various aspects of salinity as it affects rice production.

This bulletin presents the characteristics and indicators of salt-affected soils, symptoms of rice salt injury, and the cultural management practices in managing salt-affected areas. It is hoped that this publication will help farmers, agronomists, agricultural extension workers, and other stakeholders in managing salt-affected soils for rice production.

Finally, my deep appreciation and gratitude to all those behind the development of this bulletin, which in my earnest hope can be a pivotal and integral component in our pursuit of achieving the goals and objectives of the “Ginintuang Masaganang Ani” rice production program of the government.

LEOCADIO S. SEBASTIAN
Executive Director
INTRODUCTION

Plant development and successful crop production require proper soil condition, including adequate water and nutrient supply. Unfavorable soil condition have an adverse effect on plant’s growth and in severe cases hinder its effective production, thus producing marginal yield or crop failure.

Salinity is one of the major soil problems in many rice growing areas of the world. About 48 million hectares of land in humid regions of South and Southeast Asia are technically suited to rice production but remain idle or are grown with poor results due to salinity. But studies showed that sustained and profitable production of crops specifically rices on salt-affected soils is possible, if appropriate on-farm management practices are implemented.

Although saline-prone areas in the Philippines are small compared with other countries in the South and Southeast Asia, it is still a potential and important resource base for the production of rice and other related staple food. There are 400,000 ha of coastal saline soils in the Philippines, of which 100,000 ha are in mangroves, 175,000 ha are in fishponds, and 125,000 ha are idle. About 70,000 ha of rice production area in Bicol and Cagayan Valley are potentially affected by saline water intrusion, thereby needing special attention and improvement. It is imperative that rice farmers understand how plants respond to salinity, its salt tolerance and sensitivity at different stages of growth, symptoms of salt injury, and the proper approaches and techniques to make rice production viable in such adverse soil condition.
Fig 1. Coastal saline (red) soils in the Philippines. IRRI, 1986.
CHARACTERISTICS OF SALINE SOILS

- Occupy the narrow strip of flatlands situated between the shoreline and the hilly or mountainous interior part of the islands, and basin lands near bodies of seawater.

- Presence of salt-loving plants or halophytes such as nipa, bakawan lalake and noni tree.

- Presence of sufficient salts within the rice plant root area that cause decline in rice yields.

- Salt source comes from seawater intrusion within the coastal areas particularly during high tides.

- The dominant salts found in the coastal and inland soils are chloride (Cl), specifically sodium chloride (NaCl).

- During prolonged dry period, saline soils form white crusts.

Indicators of salt-affected soils

- **Physical**
  - Low-lying coastal area flooded by seawater intrusion
  - Formation of white crusts on the surface soil upon drying
  - A glossy-black color paddy soils at saturated field condition
  - Coarse-textured coastal soils that are prone to extreme seawater intrusion
  - Presence or formation of densely distributed and shallow micro-cracks on Na-saturated clayey soils upon drying; wider and deeper macro-cracks on Ca-saturated soils
Vegetation

Table 1 shows the existing vegetation indices of salt-affected soils, however, there are still some rare saline species that are yet to be evaluated or validated.

Table 1. Vegetative indices for varying saline physiographic units and degree of salinity.

<table>
<thead>
<tr>
<th>Physiographic Unit</th>
<th>Local and Scientific Names</th>
<th>Category of Salinity</th>
<th>Degree of Salinity ECe, dS/m⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal swamp</td>
<td><em>Bruguiera gymnorrhiza</em></td>
<td>Hypersaline</td>
<td>&gt; 10.0</td>
</tr>
<tr>
<td></td>
<td>Local Name: Bakawan lalake, babae, bitin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Xylocarpus granatum</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local name: Tabigi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bakawan lalake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inland saline tidal marsh</td>
<td><em>Bruguiera gymnorrhiza</em></td>
<td>Very saline</td>
<td>4.0 - 10.0</td>
</tr>
<tr>
<td></td>
<td><em>Xylocarpus granatum</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Pandanus helicopus</em> (Konig)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local names: Karagumoy (Bicol), Bariw (Visayas)</td>
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</tr>
<tr>
<td></td>
<td><em>Ipomea stolonifera</em> (Cyrill)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local name: Bayubay (Bicol)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nipa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estuarine Plain</td>
<td><em>Nypa fruticans</em> (Thurnberg)</td>
<td>Saline</td>
<td>3.0 - 4.0</td>
</tr>
<tr>
<td></td>
<td><em>Ipomea stolonifera</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inland freshwater tidal marsh</td>
<td><em>Nypa fruticans</em> (Thurnberg)</td>
<td>Moderately Saline</td>
<td>2.0 - 3.0</td>
</tr>
<tr>
<td></td>
<td><em>Scirpus maritimus</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local names: Gamat, Bawang-bawang, Buslig (Bicol); Apulid (Tagalog); Barakbak (Cagayan); Marabawang, Marilanggo (Ilocano)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barakbak</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower river terrace</td>
<td><em>Scirpus maritimus</em></td>
<td>Non-Saline</td>
<td>&lt; 2.0</td>
</tr>
</tbody>
</table>

*dS/m = decisiemens per meter*
Water

- The crystal clear state of river water during daytime
- Under the moonlight spectrum, saline water has a bright reflection
- Degree of salinity can be determined with the use of an electrical conductivity (EC) meter or a hand-held saline refractometer

Possible causes of soil salinity

1. Primary salinization
   a. Surface intrusion of saline water from seawater that results to overbank and sheet flooding of rivers and inlets or streams, brought about by tidal fluctuations and typhoon surges.
   b. Subsurface intrusion of saline water from the river to the groundwater aquifer as enhanced by increased capillary process during dry periods (high, actual surface evaporation).
   c. Release of sodium from basic primary minerals present in the soil.

2. Secondary salinization *(resulting from farmer’s interventions)*
   a. Pumping of saline water from the river for irrigation purposes. This is specifically true in rainfed lowland rice areas.
   b. Pumping of salinized groundwater using deep-well pumps for irrigation purposes.
   c. Continued use of basic fertilizers in saline areas that results in enhanced salinity; or in non-saline areas, salinity can be attributed to the residues of fertilizers that could have accumulated over time.
Symptoms of rice salt injury

- stunted growth
- reduced number of tillers
- reduced root growth
- rolling of leaves
- drying of leaves
- white leaf tips
- white blotches on the leaves
- sterile spikelets (flowers) during reproductive stage, or in severe cases, delayed flowering or no flowering at all

Symptoms of salt injury at increasing levels of salinity

- Medium salinity (3.0 - 4.5 dS/m) - nearly normal growth; some reduction in tillering; some leaves are rolled
- High salinity (5.0 - 8.5 dS/m) - reduced growth and tillering; most leaves are rolled; very few are elongating
- Very high salinity (9.0 - 14.5 dS/m) - growth completely ceased; most leaves get dry and others are drying; in extreme cases, almost all plants withered
Effects of salinity on different growth stages of rice

- High flower sterility
- Reduced grain yield

Salinity affects the growth of rice in varying degrees depending on its growth stage. Rice is tolerant during germination, becomes very sensitive during early seedling stage, gains tolerance during vegetative growth, reverts to being sensitive during pollination and fertilization, and eventually becomes tolerant at maturity.
CROP, SOIL, AND WATER MANAGEMENT OF SALT-AFFECTED RICELANDS

The success of rice production on salt-affected ricelands depends largely on the employment of the concept of avoidance of salts especially during the critical growth stages of the rice crop. This concept involves the knowledge of the physiographic setting of rice areas, frequency of tidal fluctuations and consequent surface saline water intrusion, inherent degree of soil, and water salinity at the start of each cropping season. In saline prone areas, control of salinity is the key factor for successful rice cultivation.

- **Avoidance of salts**
  
  - Proper timing of seed sowing to avoid salt injury at seedling stage. This is done before the start of the projected salt intrusion.
  
  - Knowledge on rice growth stages and the possible time of salt intrusion.
  
  - During unexpected saline water intrusion, flush out salts with freshwater, if available, and delay transplanting of seedlings until soil reaches the tolerable level of salinity (<3 dS/m).
  
  - Flushing of excess salts with non-saline irrigation water when symptoms of salt-injury have already appeared.

In saline soils, PSB Rc48 and PSB Rc90 have higher survival, productive plants, percent filled grains, weight of grains, grain yield and grain to straw ratio than rice varieties without tolerance to salinity. In addition, PSB Rc90 has good grain quality.
Use of salt-tolerant rice varieties

Table 2. Salt-tolerant rice varieties and their reaction to diseases and insect pests.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield (kg/ha)</th>
<th>Maturity (days)</th>
<th>Plant height (cm)</th>
<th>Productive tiller (No./hill)</th>
<th>Reaction to Diseases</th>
<th>Reaction to Insect Pest</th>
<th>Pest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Saline</td>
<td>Non saline</td>
<td></td>
<td></td>
<td>Blast</td>
<td>Sheath blight</td>
<td></td>
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<tr>
<td>PSB Rc48</td>
<td>2744</td>
<td>7353</td>
<td>126</td>
<td>88</td>
<td>S</td>
<td>I</td>
<td>R</td>
</tr>
<tr>
<td>(Hagonoy)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>PSB Rc50</td>
<td>2969</td>
<td>7580</td>
<td>118</td>
<td>90</td>
<td>S</td>
<td>R</td>
<td>R</td>
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<tr>
<td>(Bicol)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS</td>
</tr>
<tr>
<td>PSB Rc84</td>
<td>1967</td>
<td>4774</td>
<td>111</td>
<td>77</td>
<td>S</td>
<td>S</td>
<td>MR</td>
</tr>
<tr>
<td>(Sipocot)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS</td>
</tr>
<tr>
<td>PSB Rc86</td>
<td>2117</td>
<td>3925</td>
<td>113</td>
<td>82</td>
<td>S</td>
<td>S</td>
<td>MS</td>
</tr>
<tr>
<td>(Matnog)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MR</td>
</tr>
<tr>
<td>PSB Rc88</td>
<td>2183</td>
<td>6114</td>
<td>116</td>
<td>88</td>
<td>I</td>
<td>S</td>
<td>I</td>
</tr>
<tr>
<td>(Naga)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSB Rc90</td>
<td>3400</td>
<td>4882</td>
<td>124</td>
<td>86</td>
<td>I</td>
<td>I</td>
<td>MS</td>
</tr>
<tr>
<td>(Buguey)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS</td>
</tr>
</tbody>
</table>

* All varieties are not tolerant to tungro as in most varieties in other ecosystem.

Note: S - susceptible  MS - moderately susceptible  R - resistant  I - intermediate  MR - moderately resistant

Rice varieties and their grain quality characteristics.

**PSB Rc48 (Hagonoy)**
- % amylose = 25.80 H
- % headrice = 42.50 G2
- % acceptability in cooked form = 69.15
- % acceptability in raw form = 70.40
- % milling recovery = 64.70 G3

**PSB Rc50 (Bicol)**
- % amylose = 24.70 I
- % headrice = 45.30 G2
- % acceptability in cooked form = 76.10
- % acceptability in raw form = 44.50
- % milling recovery = 64.00 G2

**PSB Rc84 (Sipocot)**
- % amylose = 24.40 I
- % headrice = 38.80G1
- % acceptability in cooked form = 76.67
- % acceptability in raw form = 86.67
- % milling recovery = 65.90 G1
PSB Rc86 (Matnog)
- % amylose = 25.40 H
- % headrice = 46.00 G2
- % acceptability in cooked form = 70.00
- % acceptability in raw form = 83.33
- % milling recovery = 70.30 P

PSB Rc88 (Naga)
- % amylose = 22.00 I
- % headrice = 49.11 G1
- % acceptability in cooked form = 93.33
- % acceptability in raw form = 93.33
- % milling recovery = 68.32 G1

PSB Rc90 (Buguey)
- % amylose = 24.80 I
- % headrice = 56.40 G1
- % acceptability in cooked form = 68.90
- % acceptability in raw form = 90.60
- % milling recovery = 68.90 G2

Note: H - high, I - intermediate, G - grade, P - premium

Recommended Cultural Management

- Preparation of seeds for sowing
  1. Soak the seeds in clean lukewarm water for 24 hours; remove seeds that float.
  2. Drain the water and wash the seeds.
3. Place the seeds on a clean cement floor, cover with a wet sack or keep in cloth bags and incubate for 36-48 hours.

After incubation, the seeds will germinate and ready for sowing in the prepared seedbeds.

- Nursery preparation

1. *Prepare seedbed plots 2-3 days before sowing.* Sow 40-60 kg seeds in a 800 m² seedbed. Normally, 40 kg/ha is enough but more seedlings for transplanting are required to compensate for the reduced tillering of older seedlings.

2. *Establish the seedbed site on a non-saline area.* If the area is limited, a moderately saline area can be used. Be sure to use moderately saline to non-saline water in irrigating the seedbed. Ideally, it may be necessary to transport the seedlings from non-saline to saline area at transplanting.
**Priming of rice seedlings**

Priming (conditioning) of seedlings by evenly watering the seedbed with low level of salt solution can increase seedling’s adaptability to tolerance. Priming prior to transplanting is done when the seedlings are 15-18 days old. This can improve the yield by 57-70% more than the non-primed seedlings in moderately saline-prone areas.

![Average yield of PSB Rc50 and PSB Rc64 with or without low level of salt-solution (priming).](image)

**Fig 2.** Average yield of PSB Rc50 and PSB Rc64 with or without low level of salt-solution (priming).

1. Prepare low-level salt solution.
   a. Dissolve 2.0 g of table salt into 1 L of water.
   b. Compute the volume of solution required by using a constant factor of 5.0 L/sq m of seedbed.

2. Water the seedlings with low level of salt solution at 7 or 10 days before transplanting. Be sure to water the plots evenly with the solution.
Land Preparation

1. Improve the dikes surrounding the rice field to prevent the physical intrusion of saline water. This can be done by strengthening the main dikes with the use of either wooden planks or concrete blocks and increasing its height by putting more mud that will eventually dry up.

2. Make a small inlet-outlet break in the main dike to serve as entry point of fresh irrigation water, if available, and outlet for flushing brackish water.

3. Bring the salinity of the soil at minimum level by repeatedly flushing excess soluble salts, especially in extreme saline areas. This is done by repeatedly ponding fresh water into the field, puddling, and draining the soil.

flushing of salt

1. If fresh water is available for irrigation, allow soil particles to settle after puddling, before the saline water is drained out of the field. Then, introduce fresh irrigation water and repeat the whole procedure of flushing.

The frequency of flushing depends on the initial salinity level of the soil and its texture. Clayey soils require more flushing than loamy or sandy soils. In most cases, however, salinity of
the soil is low at the end of each monsoon period as a result of natural salt dilution by rain.

2. Measure the electrical conductivity of the saturation extract of the soil (ECe) using a portable EC meter or a refractometer. ECe at < 4.0 dSm⁻¹ is acceptable to commence transplanting.

- **Transplanting**
  1. Transplant only 25-30 day-old seedlings. Mature seedlings are preferred as these are more resistant to soil salinity.
  2. Flood the seedbed then, carefully pull the seedlings. Be sure not to damage the roots, as it lengthens the recovery period of the seedlings and increases its vulnerability or susceptibility to salt injury.
  3. Cut the droopy and long leaves of older rice seedlings to prevent the leaves from touching the muddy water, thus preventing possible disease infections.
  4. Follow straight row planting using 2-3 seedlings per hill at a 20 x 20 cm distance. Straight row planting enhances optimum population density, and facilitates fertilizer application and weeding operations.
  5. Avoid deep transplanting as this can cause poor tillering capacity of seedlings.
6. Always keep extra seedlings along alleyways for replanting of missing hills. Replant 1-2 weeks after transplanting.

- **Fertilizer management**

1. Apply 30-60 kg nitrogen (N) fertilizer per hectare during the wet season and 60-90 kg N/ha during dry season depending on the organic matter (OM) content of the soil. Soils with low level of OM requires higher N than soils with higher OM content. The rice crops require high N application during the dry season because of its better response to N due to abundant sunlight.

   Split application of N is best for rice plant in saline soils, one half of the recommendation is applied as basal at final harrowing of the field and the remaining N topdressed, 1/3 at 5-7 days before panicle initiation, and 1/6 at flowering.

2. Apply 20-30 kg phosphorus (P) fertilizer per hectare as basal.

3. Apply 21.0-31.5 kg potassium (K) fertilizer per hectare as basal and 9.0-13.5 kg K 5-7 days before panicle initiation.

   Sodium content of the soil is a possible constraint, since an excess of sodium in the soil can inhibit rice plant’s potassium uptake. Application of K fertilizer will reduce Na/K ratio in the soil and increase availability of K for plant uptake.

4. Apply 30 kg zinc sulfate (ZnSO₄) per hectare during the last harrowing together with the basal application of NPK, or root dipping in 2% ZnO solution is also recommended.

   Saline areas are prone to Zn deficiency especially those that have prolonged flooding, thereby application of Zn supplement is necessary and important.
- **Pest and Disease Management**
  1. Plant during the regular planting time in the area to avoid pests.
  2. Do not plant susceptible varieties in pests and diseases hot-spot areas.

- **Harvesting and Threshing**
  1. Harvest the crop when 80-85% of the grains are golden yellow.
  2. Clean the thresher before threshing, particularly if the harvest will be used as seeds.
  3. Thresh grains immediately after harvest.

- **Drying, Cleaning, and Storing**
  1. Dry the harvest immediately after threshing to preserve grain quality.
  2. Clean dried palay or seeds.
  3. Use blowers or grain cleaners to remove empty, light and diseased seeds, weed seeds, soil particles, and other plant parts.
  4. Place the clean palay or seeds in clean or new sacks.
  5. Store palay or harvested seeds properly to protect them from unfavorable weather conditions, pest and diseases, and other types of contamination.
Appendix 1. Abbreviations

- Ca$^{2+}$ - calcium
- Cl$^-$ - chloride
- CO$_3^{2-}$ - carbonate
- EC - electrical conductivity
- ECe - electrical conductivity of the saturation extract of the soil
- ECw - electrical conductivity of water
- ha - hectare
- HCO$_3^-$ - bicarbonate
- L - liter
- Mg$^{2+}$ - magnesium
- Na$^+$ - sodium
- NaCl - sodium chloride
- NO$_3^-$ - nitrate
- SO$_4^{2-}$ - sulfate
- ZnO - zinc oxide
- ZnSO$_4$ - zinc sulfate

Appendix 2. Terms used

- **Aquifer** - a water-bearing rock.
- **Decisiemens per meter (dS/m)** - unit of measurement of electrical conductivity (ECe); basically a measure of soil and water salinity.
- **Electrical conductivity (EC)** - the capacity of a substance to conduct or transmit electric current. In soils or water, measured in siemens/meter, and related to dissolved solutes. ECe is the electrical conductivity of the saturated soil paste.
- **Flushing** - ponding of fresh irrigation water into salt-affected soils, puddling and draining the soil to remove excess salts.
Nutrient element ratio - the proportion of the nutrient element within the soil exchange complex, which serves as indicator of pedogenic processes, e.g. salinization, acidification, and alkalinization, etc.

Priming of rice seedlings - conditioning or adaptation of rice seedlings to salinity by watering evenly the seedbed with low NaCl solution.

Puddling - mixing soil with water to make the soil impenetrable to water. This condition eases transplanting and reduces water losses through percolation. It results in the destruction of 91-100% of micropores volume and restricts porosity to only the space occupied by the water film around the clay particles.

Saline soil - a soil containing sufficient soluble salts to impair its productivity. The ECe is >4 dS/m, the exchangeable sodium adsorption ratio is less than 13, and the pH is <8.5.

Salinization - the process of accumulation of salts in the soil.

Salt-affected soil - soil that has been adversely modified for the growth of most crop plants with the presence of soluble salts, exchangeable sodium, or both.

Salt-water refractometer - a hand held field instrument used to determine the approximate salt concentration within the saline intruded irrigation water. Values are usually in parts per thousand (ppt) or percent salinity.

Soil salinity - the amount of a soluble salts in the soil, expressed in terms of percentage, milligrams per kilogram, parts per million (ppm), or electrical conductivity of the saturation extract of soil (ECe).

Soil macro-cracks - a qualitative soil physical observation wherein the calcium and/or magnesium dominated soil matrix shrinks upon drying and is exhibited as sparsely distributed wide surface - deep cracks, the depth of which is >50 cm.

Soil micro-cracks - a qualitative soil physical observation wherein the sodium saturated soil matrix shrinks upon drying and is manifested as densely distributed narrow surface-shallow cracks, the depth of which ranges from 20 to 50 cm.
References


U.S. Salinity Laboratory staff. 1954. Diagnosis and improvement of saline and alkaline soils. USDA Agric. Handbook #60. Washington, D.C., USA.
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Published 2001 by the Philippine Rice Research Institute. Readers are encouraged to reproduce the contents of this bulletin with acknowledgment.

ACKNOWLEDGMENT:
  • Bureau of Soils and Water Management (BSWM)
  • Department of Soil Science, Central Luzon State University (CLSU)
  • Department of Agriculture-Bicol Integrated Agricultural Research Center (DA-BIARC)
  • Department of Agriculture-Cagayan Valley Lowland Marine Research Outreach Station (DA-CVLMROS)
  • Department of Agriculture-Western Visayas Integrated Agricultural Research Center (DA-WESVIARC)
  • International Rice Research Institute (IRRI)
The Philippine Rice Research Institute (PhilRice) is a government corporation attached to the Department of Agriculture (DA). Executive Order 1061 approved on November 5, 1985 and amended by EO 60 dated Nov. 7, 1986, created PhilRice to help develop high-yielding technologies so that farmers can produce enough rice for all Filipinos. PhilRice accomplishes this mission through research, technology promotion, and policy advocacy, which are implemented through a network that includes 57 agencies and 115 seed centers strategically located nationwide.

Its interdisciplinary programs include the following: (1) direct-seeded and (2) transplanted irrigated lowland rice; (3) hybrid rice; (4) rice for adverse environments; (5) rice-based farming systems; (6) rice and rice-based products; (7) policy research and advocacy; and (8) technology promotion. With these programs, PhilRice aims to develop and promote technologies that are ecosystem-based, location- and problem-specific, and profitable to the Filipino farmers.

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