

Acid soil management

in north eastern hill region of India

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Acid soil is dominant in North-Eastern Region (NER) of India comprising 26.22 million hectares out of which 21.26 million hectares is affected by soil acidity. Distribution of acid soil in North-Eastern Hill (NEH) region varies from 80–100%. Acid soil is deficient in P, Ca, Mg, Mo and B, and as a result limits crop growth and yield to varying extent. Management of acid soil is important to enhance the productivity of the soil and performance of the crops. Soil amendment with lime, growing tolerant crops and varieties, organic amendments, viz. poultry manure, farm yard manure, pig manure, green manures and biochar, good agronomic practices, adoption of agro-forestry are the promising practices suitable for enhancing the productivity of acid soils. Central Agricultural University (CAU) gave way to a new centre for research on acid soil management. The goal is to make CAU a scientific leader in natural agriculture by providing and implementing innovative approaches and game changer technologies such as natural farming, advanced research on organic farming, integrated farming system, acid soil management, and rice-fallow system production.

Keywords: Acid soil, Lime, NEH region, Nutrient deficiency, Organic manures

THE North-Eastern Region of India is characterised by diverse agro-climatic and geographical situations. The region has a vast coverage of forest which is nearly 55% of the total geographical area. About 16.6% of area is under cultivation and 8.62% of area is estimated to be unavailable for cultivation. The low area under agricultural crops is mainly due to the natural physiographic features of the region, as majority of the land has more than 15% slope, undulating topography, highly eroded and degraded soils, and inaccessible terrain. The major factors which lead to the lower productivity of crops in this region are use of local varieties, low consumption of agro-chemicals, low moisture retention capacity of upland soil, undulating topography, no facility of drainage in valley during monsoon and lack of irrigation facilities during winter months and low sunshine hours along with traditional management

practices. In addition to this, heavy rainfall received in the region leads to soil acidity which further aggravates the low agricultural productivity and consequently NER contributes only 1.5% to the national food grain production.

Soil acidity is an important abiotic stress which negatively affects crop growth and yield. About 50% of the world's potentially arable land in humid tropics is affected by soil acidity. In India, acid soils occupy about 90 million hectares (mha). Estimates showed that about 25 mha of the cultivated land is strong to moderately acidic (pH <5.5), while 23 mha is slightly acidic (pH 5.5–6.5) in India. Majority of these soils (54%) are concentrated in NER of India where more than 90% area is affected by soil acidity, with around 65% of the area being under extreme forms of soil acidity (pH below 5.5). The production potential of acid soils is generally very low due to poor fertility of these soils.

The adverse effect of acid soils on plant growth is mainly related to the presence of Al, Fe and Mn in toxic concentration, deficiency of P, Ca and Mg, low base saturation, impaired biological activity and other acidity-induced soil fertility and plant nutritional problems. Since most acid soils are less productive due to low fertility, low water retention and poor physico-chemical conditions, it may be said that soil acidity and poverty are synonymous. Hence, amelioration of soil acidity is a crucial challenge for improving crop productivity for enhancing food security.

Distribution of Acid Soil in North-Eastern Region

More than 21 mha of acid soils are found in NER of India, whereas, more than 16 mha area is affected by soil acidity in North-Eastern Hill (NEH) region, excluding the state of Assam. Among the North-Eastern states, Arunachal Pradesh has



Acid soils at College of Agriculture, Kyrdenkulai; failure of maize crop due to soil acidity

maximum area under acidity (6.79 mha) followed by Assam (4.68 mha), Meghalaya (2.24 mha) and Manipur (2.19 mha) (Table 1). In Assam where about one-third of soils are slightly-acidic in nature. A major part of area in Arunachal Pradesh (4.8 mha) falls under the category of strongly acidic soils ($pH < 4.50$). The districts having relatively more area under acid soils are east Khasi hills and west Khasi hills of Meghalaya, Tuensang and Kohima in Nagaland, Aizawal in Mizoram, west Siang and Dibang valley in Arunachal Pradesh, Churachandpur in Manipur, Karbi Anglong in Assam, west Tripura and south Tripura in Tripura and north Sikkim in Sikkim. The extent of occurrence of acid soils is as high as 10% in Nagaland and Tripura, 99.87% in Meghalaya, 98.07% in Manipur and 97.25 % in Mizoram.

Acid soil– a Silent Killer

Acidity in the soil, if left unmanaged, may have detrimental effect on soil quality and plant growth. The acid soils are generally low in available P and exchangeable bases such as K and Ca, and have low base saturation, low cation exchange capacity (CEC) and high levels of potentially toxic Al, Fe and Mn. Hence, it is commonly said that the productivity of acid soils is very low (< 1 t/ha) due to deficiencies of P, Ca, Mg, Mo, and B, and toxicities of Al and Fe. The availability of boron (B) reduces in acid soil due to adsorption on sesquioxide, iron and aluminium hydroxy compounds. Kaolinitic and illitic type of clay minerals are dominant in acid soils. The pH of the soil affects the bioavailability of plant nutrients and

indirectly crop growth.

The adverse effect of acid soils on plant growth is mainly related to the presence of Al, Mn and Fe and in toxic concentration, deficiency of Ca and Mg, nutrient imbalances and microbial imbalances. The Aluminium toxicity has multiple effects on plant growth, of which inhibition of root growth is possibly the most important. High Al ion concentration at the root surface may prevent the root from taking up phosphate and the Al inside the living cell may interfere with sugar phosphorylation. The Al toxicity is a major problem in both upland and lowland soils. Al toxicity has been reported to cause direct inhibition of root elongation and it further interferes with uptake of plant nutrients. Al toxicity restricts the absorption and translocation of P, Ca, Fe and Mn. It also causes wilting of plants and inhibits the microbial activity in the soil apart from affecting cell division and formation of DNA and respiration. Hence, aluminium toxicity can be considered as a primary limiting factor in acid soils for plant growth and development. At the same time, manganese toxicity may show up in soils having pH below 5 when Mn accumulates in plant tissue in toxic concentration and interferes with plant metabolism.

Besides these, the acid soils have high phosphate fixation capacity. The status of available micronutrient elements, except molybdenum, is generally adequate in these soils. Strongly acidic soils are deficient in available Mo because it reacts with the silicates, iron and aluminium compounds.

Soil acidity alters the kind, number and activities of microorganisms involved in soil organic matter transformation and subsequent availability of organically bound N, P, S and other micronutrients. Soil acidity also inhibits biological nitrogen fixation. The population of bacteria and actinomycetes is lower and those of fungi is higher in acid soils compared to neutral soils. Raising good crop under acid soil is a very challenging task. Since crop-livestock-human systems are interrelated, poor crop growth and nutrition directly or indirectly affects the livestock as well as the human health.

Management Strategy for Acid Soil

The management of acid soil should aim at improving the production potential of the soil by either amendments or manipulation of agricultural practices to obtain optimum yield under acidic conditions. However, even within the crop, the performance of varieties also varies under acidic conditions. Acid soils can be managed either by growing crops suitable for a particular soil pH or by ameliorating the soils through application of amendments, either inorganic or organic, which can counteract soil acidity. Besides these, good agronomic management practices are also important to manage soil acidity to enhance the productivity of the crop in acidic environment. Some practices are given here.

Growing acid-tolerant crops

Traditionally, farmers of acid soil regions like to grow rice (*Oryza sativa*) irrespective of the type of land i.e. upland, medium and low land.

Table 1. Relative tolerance of fruit crops to soil acidity

Slightly tolerant to acid soil (pH 6.8–6.0)	Moderately tolerant (pH 6.8–5.5)	Highly tolerant to acid soil (pH 6.8–5.0)
Mango (<i>Mangifera indica</i>), Citrus (<i>Citrus</i> spp.), Banana (<i>Musa</i> spp.), Guava (<i>Psidium guajava</i>), Papaya (<i>Carica papaya</i>), Apple (<i>Malus domestica</i>), Peach (<i>Prunus persica</i>), Carambola (<i>Averrhoa carambola</i>), Kiwi fruit (<i>Actinidia deliciosa</i>).	Pineapple (<i>Ananas comosus</i>), Orange (<i>Citrus sinensis</i>), Litchi (<i>Litchi chinensis</i>), Passion fruit (<i>Passiflora edulis</i>), Jackfruit (<i>Artocarpus heterophyllus</i>).	Strawberry (<i>Fragaria × ananassa</i>), Gooseberry (<i>Emblica officinalis</i>), Bael (<i>Aegle marmelos</i>), Elephant apple (<i>Dillenia indica</i>), Plum (<i>Prunus domestica</i>).

Table 2. Relative tolerance of vegetables to soil acidity

Slightly tolerant (pH 6.8–6.0)	Moderately tolerant (pH 6.8–5.5)	Highly tolerant (pH 6.8–5.0)
Beet (<i>Beta vulgaris</i>), Broccoli (<i>Brassica oleracea</i> var. <i>italica</i>), Cabbage (<i>Brassica oleracea</i> var. <i>capitata</i>), Cauliflower (<i>Brassica oleracea</i> var. <i>botrytis</i>), Celery (<i>Apium graveolens</i>), Spinach (<i>Spinacia oleracea</i>), Chinese cabbage (<i>Brassica chinensis</i>), Leek (<i>Allium porrum</i>).	French bean (<i>Phaseolus vulgaris</i>), Carrot (<i>Daucus carota</i>), Cucumber (<i>Cucumis sativum</i>), Brinjal (<i>Solanum melongena</i>), Knol-Khol (<i>Brassica oleracea</i> var. <i>caulorapa</i>), Pea (<i>Pisum sativum</i>), Chilli (<i>Capsicum annuum</i>), Pumpkin (<i>Cucurbita moschata</i>), Lima bean (<i>Phaseolus lunatus</i>), Radish (<i>Raphanus sativus</i>), Summer squash (<i>Cucurbita pepo</i>), Winter squash (<i>Cucurbita maxima</i>), Tomato (<i>Lycopersicon esculentum</i>), Colocasia (<i>Colocasia esculentum</i>), Garlic (<i>Allium sativum</i>).	Potato (<i>Solanum tuberosum</i>), Sweet Potato (<i>Ipomea batatas</i>), Chow-Chow (<i>Sechium edule</i>), Yam (<i>Amorphophalus companulatus</i>), Dioscorea (<i>Dioscorea</i> spp.), Watermelon (<i>Citrullus lanatus</i>), Chicory (<i>Cichorium intybus</i>).

Rice has good tolerance to acidity since flooding of rice fields raises the pH to almost neutrality. At the same time, short duration rice grown in uplands also has the potential to tolerate acidity. Minor millet [such as proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*), barnyard millet (*Echinochloa colona*), kodo millet (*Paspalum scrobiculatum*)] and finger millet (*Eleusine coracana*) are quite tolerant to acidity. Bengal gram (*Cicer arietinum*), lentil (*Lens culinaris*), groundnut (*Arachis hypogaea*), maize (*Zea mays*), sorghum (*Sorghum bicolor*) and peas (*Pisum sativum*) are moderately tolerant to acid soils. On the other hand, pigeon pea (*Cajanus cajan*), soybean (*Glycine max*) and cotton (*Gossypium barbadense*) are highly sensitive to soil acidity. The horticultural crops are seen to have tolerance or affinity

to specific soil pH and according to soil reaction these are classified into three groups, viz. slightly tolerant to acid soils, moderately tolerant to acid soils, and highly tolerant to acid soils (Table 1 and 2).

Table 3. Identified crop varieties relatively tolerant to soil acidity (pH<5.5)

State	Crop	Varieties
Assam	Rapeseed	Varuna, Sonmukhi
	Summer green gram	K851, Sonmugu
Meghalaya	French bean	HUR - 15
Jharkhand	Black gram	KU - 301
Orissa	Groundnut	Smruti
	Pigeonpea	UPAS - 120
West Bengal	Mustard	Sanjukta, Pusa bold
	Wheat	K9107, PBW343
Kerala	Vegetable Cowpea	Bhagya Lakshmi
	Cowpea (Bushtype)	V - 16
Himachal Pradesh	Soybean	Bragg, Pb1, Harasoya
	Brassica	ONK1, HPN3, Hoyala

Growing acid tolerant crop varieties is another option. With the promotion of genotypes and/or varieties relatively tolerant to soil acidity, there is a possibility that farmers may get 2 to 3 times of crop yield as compared to the yield that they are getting now. The different varieties of crops, relatively tolerant to soil acidity, which are commonly grown in acid soils in different states of India are given in Table 3.

Application of inorganic amendments

Lime application: Application of lime is the most desirable and effective practice for amelioration of soil acidity and consequently improves crop production. Among the naturally occurring lime sources, calcitic, dolomitic and stromatolytic limestones are important carbonates. The most commonly used liming materials are ground limestone, dolomitic ground limestone, chalk, ground chalk, burnt lime and hydrated lime. Lime raises the soil pH, and thereby, affects the availability and solubility of most of the plant nutrients. It raises the level of exchangeable base status of Ca and Mg, influences the nutrient uptake of plant by producing a certain antagonistic effect, reduces toxic concentration of Al and Mn by neutralizing the effect, improves soil structure and hydraulic conductivity and promotes root distribution. In spite of the benefits liming is questionable because of high lime requirements in most of the acid soils of NEH region and

the effect of liming does not persist for long. Consequently, few studies have recommended that reduced dose of lime (one-tenth to one-fifth of lime requirement) should be applied along with fertilizers in furrows at the time of sowing. The availability of cheap and effective liming materials is highly important to popularize liming among the farmers and for the success of acid soil amelioration. The agricultural grade limestone powder and marketable lime are effective, but may not be economical for the farmers besides abundant availability at all places. A number of industrial by-products like basic slag, lime sludge, press mud and paper mill sludge, etc. are considered as rich sources of Ca and have the potential to serve as cheap liming materials in some areas.

Lime sludge is the solid waste produced as a part of the process that converts wood/bamboo chips into pulp for paper. Calcium carbonate (CaCO_3) is the major component of lime sludge. Paper mill sludge (PMS), a by-product of paper mill that contains CaCO_3 , can be used for reclamation of soil acidity. Studies also indicated a promising potential for PMS to be used as an inexpensive source of available lime for correction of soil acidity.

Phosphogypsum: It is a by-product of diammonium phosphate factory located at Paradip of Orissa. Phosphogypsum contains 16% sulphur (S), 20-21% calcium (Ca) and 0.2-1.2% phosphorus (P). Since Ca in Phosphogypsum can leach down faster compared to lime in light textured soils, sub-soil acidity could be ameliorated with resultant reduction of aluminium toxicity and Ca deficiency.

Apart from these, since acid soils have high phosphate fixing capacity, its inherent acidity and acidity created in the root rhizosphere can dissolve the insoluble rock phosphate and release P. Hence, when the soil pH is less than 5.5, ground rock phosphate as such can be applied. However, when the pH of soil is between 5.6 and 6.5, a mixture of rock phosphate and superphosphate in 1:1 ratio is used for better economy as super

phosphate will act as a starter.

Application of organic amendments

The conventional liming materials such as calcium carbonate and calcium oxide are not only scarce and expensive; their application rate is also very high which ultimately leads to higher production cost per unit area. Consequently, need of the hour is to focus research on development of locally adapted indigenous and sustainable way of managing soil acidity. Organic waste amendments, such as farm yard manure (FYM), green manures, poultry manure, pig manure, biochar etc., are usually used as an alternative to lime application for the reclamation of acid soil infertility and build-up of depleted soil organic matter. External application of animal manure has been reported to increase soil pH and decline Al toxicity in acid soil. At the same time, animal manure supplies the crops with available N, P, and K and improves physico-chemical and biological properties of soil.

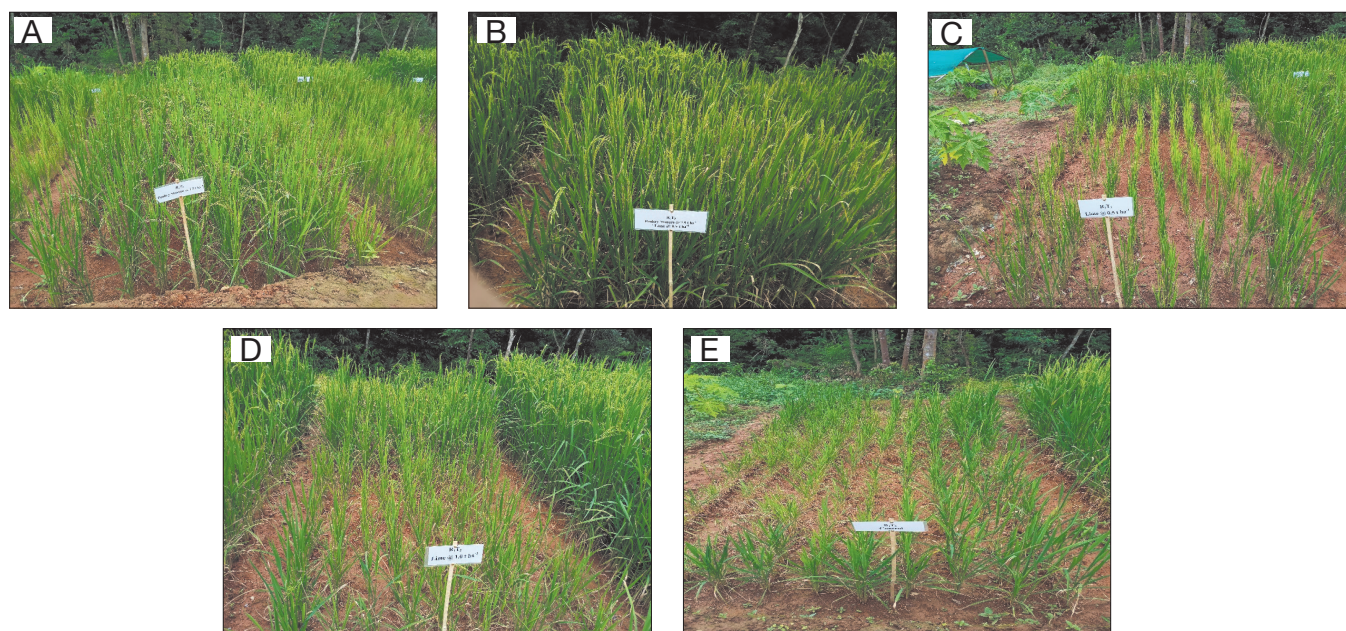
Poultry manure: Indiscriminate dumping of poultry manure on the environment have been a source of concern to poultry farmers, environmentalists and the general public. However, the same poultry manure can be utilised as an amendment for the management of acidic soil in tropical and sub-tropical countries. On an average, poultry manure contains 3-5% nitrogen, 1.5-3.5% phosphorus, 1.5-3.0% potassium and micronutrients at considerable amount. Poultry manure contains high ammoniacal-N ($\text{NH}_4\text{-N}$) and uric acid which is capable of converting a large percentage of N to nitrate-N ($\text{NO}_3\text{-N}$) within a week as uric acid metabolizes rapidly to $\text{NH}_4\text{-N}$ in most soils. Moreover, the use of poultry manure has overtaken the use of other organic manures, such as pig manure, due to its high content of both macronutrients (N, P, and K) and micronutrients (Fe, Mn, Cu and B) besides improving the soil structure, nutrient retention, aeration, infiltration and water holding capacity of soil. Since poultry manure is cheap source of

both macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Fe, Mn, Cu and B) and has the potential to increase the porosity and microbial activity in soil, it can be used as an alternative to compensate for shortage of FYM in NEH region for management of acid soil. Moreover, the application of poultry manure elevates the soil pH mainly due to the presence of substantial amount of CaCO_3 in it. Research conducted at College of Agriculture, Kyrdekulai has indicated that application of poultry manure @7.5 t/ha is effective in managing the acid soil for cultivation of upland rice compared to application of lime either at 0.5 or 1.0 t/ha.

Pig manure: Pig farming is one of the major sources of income for small and marginal farmers of NEH region. Pig manure can be considered as an important source of nutrients for crop production due to the presence of N, P, K, Ca, Mg, S, Mn, Cu, Zn, Cl, B, Fe, and Mo. Although pig manure contains relatively lower amounts of N and K, but it has higher levels of Cu and Zn because these nutrients are added to feed. Although application of pig manure sometimes helps to improve the soil acidity, however, further research is needed to prove its authenticity.

Green manures: Green manuring can be defined as the growth of a crop for the specific purpose of incorporating it into soil while green, or soon after maturity with a view to improve the soil and benefit subsequent crops. Green underdecomposed material used as manure is called green manure. The most important green manure crops are Sunnhemp, Dhaincha, Clusterbeans, *Sesbania rostrata* etc.

Application of green manures in acid soils can also reduce aluminium toxicity and subsequently increase crop yield. Addition of green manure also improves soil structure and increases water holding capacity of soil. Studies indicated that addition of green manure in acid sulphate soil resulted in significant reduction in aluminium concentration. Moreover, peat mixed with green manure and rice



Effect of poultry manure and lime for the management of acid soil at College of Agriculture, Kyrdekulai (a. Poultry manure @7.5 t/ha; b. Poultry manure @2.5 t/ha+ Lime @0.5 t/ha; c. Lime @0.5 t/ha; d. Lime @1.0 t/ha; e. Control)

straw synergistically promoted complexation and chelation of monomeric aluminium, presumably forming aluminium-organic acid complex in the soil. However, higher application rate of green manures and/or organic manures is practically not feasible thus for increasing soil pH, decreasing concentration of phytotoxic aluminium and reducing lime requirements, combined application of lime and organic manure is advisable for management of acid soil.

Biochar: Biochar generally refers to the black carbon or carbon-rich solid product which is produced by pyrolysis of biomass under oxygen-free environment, so that it is not subjected to complete combustion. Use of biochar as soil amendment has been receiving significant attention for various reasons such as neutralizing acidity in soil, creating a carbon sink to mitigate global warming, increasing soil water holding capacity, reducing greenhouse gas emissions and stabilizing mobile heavy metals, pesticides and other organic pollutants in soil. Free bases present in biochar such as Ca, Mg, and K can be readily released into the soil solution which leads to net increase of soil pH and exchangeable bases and ultimately helps to mitigate the

soil acidity. Thus, biochar could be used as an alternative of lime for management of soil acidity in NEH region. However, its production cost and availability restrict its use in agriculture as an amendment.

Good agronomic practices

Crop Scheduling: In order to get good crop growth and productivity, under rainfed conditions, highly responsive crops like cotton, soybean, pigeon pea, groundnut, French bean etc. should be grown in the first year of liming. This should be followed by medium responsive crops like maize and wheat in the subsequent seasons. Cultivation of lowest responsive crops like millets, rice, barley, linseed etc. should be done in the last season and/or year prior to commencement of the next liming schedule.

Crop diversification: Location specific crop diversification with acid tolerant crops like rice, tea, groundnut, maize etc. should be followed. Crop diversification especially in rainfed uplands through intercropping and in rainfed medium and lowlands through sequence cropping is essential for increased agricultural productivity of acid soil regions.

Lime application techniques: Lime placement in soil is highly important in determining reactivity

and movement into the sub soil. Liming materials have very limited movement into the soil without incorporation. Hence, lime is usually broadcasted on the soil surface and wherever possible, the added lime should be incorporated in the soil as deeply as possible by a plough or disc harrow. It has been usually suggested that the recommendation of lime should be made in small doses to make it more cost-effective and for better acceptability of liming practice by resource poor farmers. It was also suggested to apply the lime with basal dose of fertilizers (part of N + full dose of P and K) manually or through seed-cum-fertilizer drill at the time of sowing.

Seed priming: Seed priming is a pre-sowing treatment which leads to a physiological state that enables seed to germinate more efficiently and ultimately helps in strengthening crop establishment and increase the crop yields under adverse situation. Seed priming with calcium helped improve the groundnut seedling survival in acid soil in a study.

Integrated nutrient management practice: Integrated nutrient management (inclusive of lime, organic manure and inorganic fertilizers) is often advocated to boost the crop productivity in acid soils. Research conducted at ICAR-

Research Complex for NEH region indicated that integrated nutrient management practice inclusive of liming, if adopted properly, can lead to more than three-fold increase in maize productivity in acidic soils of Meghalaya and other North-Eastern states of India.

Growing of multi-purpose tree species: The multi-purpose tree species (MPTs), besides furnishing the multiple outputs like fuel, fodder, timber and other miscellaneous products, help in improvement of soil health and other ecological conditions. Studies revealed that MPTs with greater surface cover, constant leaf litter fall, and extensive root system increased soil organic carbon content, porosity, aggregate stability and available soil moisture by 33.2%, 10.9%, 24.0%, and 33.2%, respectively, and simultaneously reduced bulk density and erosion ratio by 15.9% and 39.5%, respectively in acid soils North-East India.

Adoption of agro-forestry system: Agro-forestry system (AFS) has become an alternative approach

of integrated land management system not only for renewable resource production but also for improving soil health and ecological conditions. A study indicated that in all the AFS, significant (1.17-1.65-fold) increase in organic carbon was found as compared to initial status, the maximum contribution being by silvi-horti-pastoral AFS. The same system also registered 43.2% higher exchangeable Al compared to natural forest and consequently a maximum decrease of 0.50 units in pH. Moreover, the exchangeable Ca, Mg, Na, K, and Al and available N and P content were higher in all the systems compared to natural forest. It is suggested that AFS could be used as a potential alternative approach for management of acid soil in NEH region of India.

Crop residues: Crop residues can improve soil structure, increase organic matter content in the soil. Organic matter addition as crop residues in rotation or as intercrops serves as components of acid soil management systems. Moreover, the application of regular decomposed

organic matter to the soil reduces the concentration of Al and Fe and increases the availability of P in acid soils. Studies indicated that addition of grass residues substantially increased the maize yield and the concentrations of exchangeable K, Ca and Mg and extractable P in acid soils.

SUMMARY

North-Eastern Hill Region of India has very High amount of acid soil. Acid soils are deficient in most of the nutrients and lead to low agricultural productivity. Management of acid soils is essential to increase agricultural produce and thereby income. Growing acid-tolerant crops and varieties, using poultry and pig manure, agro-forestry, integrated farming system are some of the ways to manage acid soils.

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About Our New Project Director



Dr Suresh Kumar Malhotra, joined as Project Director, ICAR-Directorate of Knowledge Management in Agriculture. Before taking over this position, he has served at positions of Agriculture and Horticulture Commissioner, in the Ministry of Agriculture & Farmers' Welfare and Assistant Director General (Horticultural Science) in ICAR. He has more than 32 years of experience in Research and Development in Agriculture. He has provided leadership in development of agriculture in the country through policy planning, programme development, coordination, execution, supervision of R&D multidisciplinary activities. He administered the National Food Security Mission programme which ensures food security of the country. Country has achieved highest ever food grain production continuously for the

last five years during his tenure. His concerted efforts as a team made India self-sufficient in pulses production. He is the architect of Per Drop More Crop programme under PMKSY, High value agriculture, National Saffron Mission, National Pulses Mission, National Millets Mission Targeting Rice Fallow Area, and National Bee and Honey Mission programmes. He renewed the regulatory systems of the country related to pesticides including biopesticides, fertilizers involving biofertilizers, biostimulants regulation and for seed certification ensuring quality input system in agriculture. As a scientist, his research contributions to the agriculture science involved development of 15 high yielding varieties and technologies for spices, which are now basis of cultivation in the rainfed farming system. There are 312 publications to his credit. His outstanding contribution in agriculture has earned him 12 awards and 7 fellowships. He is widely travelled and represented India in more than 21 international programmes of FAO, CODEX, G20, SAARC, WHO, UNECE, CGIAR, ADB, BRICS, G4, SCO, CGIAR institutes (CIMMYT, ICRISAT, ICARDA, CIPA, Bioversity International, AVRDC). As a Chairman of more than 30 high powered committees, task forces he has guided and provided solutions to emerging problems in agriculture.