IMPROVING THE FERTILITY OF ALKALINE SOILS THROUGH SOIL AMENDMENTS

Kothur Village, Midjil Mandal, Mahabubnagar District, Andhra Pradesh, India

INDEX

IMPROVING THE FERTILITY OF ALKALINE SOILS THROUGH SOIL AMENDMENTS

Kothur Village, Midjil Mandal, Mahabubnagar District, Andhra Pradesh, India

Key words: Soil, Alkalinity, Fertility, Charcoal, Paddy, Cotton, Gypsum, Sand, Soil Microbes, Micro-nutrients.

1. INTRODUCTION

In Kothur village using Charcoal Plus amendments the alkaline soil fertility improvement was experimented with pilot farmers on trial basis. In Kothur village, Midjil Mandal parts of the area are having alkaline soils. These areas are not suitable for growth of many plants, as a result majority of the farmers, with fields having alkaline soils have left their respective fields fallow. P. juliflora is the plant, which is highly adaptive to growing in alkaline soils, is growing abundantly in these type of soils in this village. This plant presently covers nearly 250 acres of the geographical area i.e., about 30 % of the total geographical area of about 830 acres. Therefore to improve the fertility of alkaline soils, on pilot basis a method has been evolved and implemented. Three pilot farmers were selected with half an acre of field each, in Kothur village. Charcoal plus other soil amendments were done to improve the soil fertility, called Terra Preta Nova – similar to a very ancient practice in Amazon basin.

2. BACKGROUND

Terra Preta ("dark soil" in Portuguese) refers to expanses of very dark, fertile anthropogenic soils found in the Amazon Basin. It owes its name to its very high charcoal content. It is also known as "Amazonian dark earth" or "Indian black earth". In Portuguese its full name is "Terra Preta do índio" or "Terra preta de índio".

Terra preta is characterized by the presence of low-temperature charcoal in high concentrations; of high quantities of pottery shards; of organic matter such as plant residues, animal faeces, fish and animal bones and other material; and of nutrients such as nitrogen (N), phosphorus (P), calcium (Ca), zinc (Zn), manganese (Mn)[1]. It also shows high levels of microorganic activities and other specific characteristics within its particular ecosystem.

The advancement of the formation of Terra Preta soils work may take some time in order to rediscover the soil recipe that has all of the qualities of the original Terra Preta soils. The study of charcoal use in soil is just beginning, the possibilities are numerous, and the research work yet to be done is enormous. (Sean Barry, 2008). However the following benefits are identified with additions of charcoal and other additives: Enhanced plant growth, reduced fertilizer requirement, reduced leaching of nutrients, stored carbon in a long term stable sink – carbon sequestration, improved soil water handling characteristics, increased soil microbial biomass and increased arbuscular mycorrhyzal fungi.

3. OBJECTIVES

To test on trial basis, the effect of charcoal and other additives on the fertility of alkaline soils for increased crop production.

4. METHODOLOGY

A set of questions were asked pertinent to the process and a semi-structured format was prepared for collection of information.

5. FACILITATION PROCESS AND RESULTS

Selection of experimental plots

Three farmers were selected, with half an acre of field size having alkaline soils in which charcoal and other amendments were made. Three adjacent fields were also selected as control fields for the respective farmers. Soil testing of the alkaline soils was carried for understanding the physical and chemical properties of the soils. Among the three selected fields one field was rain fed, where Cotton crop was grown and the other two fields were under irrigation and in which the farmers have grown Paddy during Kharif 2007 and Rabi 2007 seasons.

Awareness creation for participation:

A meeting with progressive farmers was organized in Kothur village, where Dr. Reddy, explained the farmers regarding the use and application of charcoal as a component in improving the fertility of the alkaline soils. Some charcoal pieces were brought for demonstration and to explain its use and good qualities.

Using high resolution imageries taken from 'Google Earth', the fields with intense alkaline soils were identified. In the imageries, barren alkaline soils appear white / grey in tone that is due to reflection of light and also indirectly the fields covered with Prosopis Juliflora biomass indicate alkaline soils to some extent. From those selected areas three farmers have come forward to try the method designed by Dr. Reddy, in their respective half acre size fields. Regarding the charcoal required for application, there is abundant Prosopis juliflora in the village which was converted into charcoal. The logistics and the cost of charcoal production was discussed with the farmers. For applying about 1500 kgs of charcoal per acre, it would cost them about Rs. 3000 (at the rate of Rs. 2 per kg if produced locally by the farmer, which is the labor cost of farmer himself).

Four alkaline soil samples from the selected field areas were analyzed in soil testing lab, the test results and the suggested recommendations are as follows:

`	**Soil Testing report Kothur village, Midjil Mandal**			
	1	2	3	4
Survey No.	289		23	367
Soil type	Neutral	Neutral	Neutral	Neutral
pH	8.81	8.86	9.21	9.04
Electrical Conductivity (E.C.)	0.79	0.83	0.33	0.33
O.C.	Low	Low	Low	High
P (Kg/acre)	17	13.6	15.3	17
K (Kg/acre)	130	150	125	145
Zinc (Kg/acre)	0.65	0.65	0.65	0.65
Gypsum (Kg/acre)	324	440	405	344

Soil amendment recommendations suggested for improving the fertility of alkaline soils.

#	**Soil amendments as recommended* (per acre)**		
1	Charcoal	1500 kgs.	Thoroughly clean the charcoal in water with out any traces of ash and apply. Costs the farmer about Rs. 3000 @ Rs. 2 per kg if produced by

			farmer himself.
2	Sand	10 tractor loads (@ 5 tons per tractor load is about 50 tons)	Costs the farmer about Rs.3000
3	Gypsum	300 kgs.	Costs the farmer about Rs. 300
4	Vermicompost / FYM	4 tons	
5	Urea (N)	50 kgs.	
6	Super Phosphate (P)	70 kgs.	
7	Muriate of Potash (K)	10 kgs.	
8	Zinc (Zn)	20 kgs.	
	Soil Microbes		
10	Aztobactor	1 kg	Mix well with 50 kgs. of well Cleaned Charcoal in water and 50 kgs. of FYM / Vermicompost and by packing in Gunny bags cure it by sprinkling water for 10-15 days for spreading it in the field
11	Tricoderma Viridea	1 kg	
12	Azospirillum	1 kg	
13	Pseudomonas fluorescence	1 kg	

**Note: These recommendations were made on trail basis based on the soil quality and considering existing practices. Regarding quantity of charcoal to be applied and processing it before application, was decided by Dr. Reddy on a trail basis, as there is no scientific methodology developed yet.*

Application of the soil microbes: A mix consisting of 50 kgs of Charcoal and 50 kgs of farmyard manure was divided into four parts and mixed with half kilogram of each of the four selected soil-microbes - Aztobactor, Trichoderma Viridea, Azospirillum and Pseudomonas fluorescence. This mixed material was filled in four *gunny* bags for about twelve days and everyday, water was sprinkled on these bags. At the end this material was used in the selected fields. The above process multiplies the soil microbes and can easily cover wider area when applied in the field.

Stages followed during the implementation:

After application of sand and charcoal in the fields, deep ploughing of the fields was done by farmers. Later farmers applied Gypsum, farm yard manure, Zinc and single Super Phosphate as suggested. Soil-microbes culture, which was developed was spread in the entire fields. 50% of the Urea was used, at the time when the crop was young, and the rest of 50% urea was used after about 35 days age of the crop.

In this method there is scope to train farmers in production, process and application of charcoal on their own, and farmers having bullock carts can transport the sand available from the nearby stream which would reduce the cost of application of charcoal and sand considerably.

Table 1 Count of tillers in the paddy fields with Charcoal Plus amendments and Control fields. Kharif 2007.

Kharif 2007

Mr. Narasimha Reddy, Kothur Village, Midjil Mandal, Mahabubnagar, Andhra Pradesh, India.														
	Samples										Total	Avg	Max	Min
	1	2	3	4	5	6	7	8	9	10				
Alkaline soil treated with charcoal	40	27	48	44	40	50	51	31	52	42	425	43	52	27
Control Field	29	30	35	26	26	30	23	35	27	28	289	29	35	23
Mr. Venkataiaha, Kothur Village, Midjil Mandal, Mahabubnagar, Andhra Pradesh, India.														
	Samples										Total	Avg	Max	Min
	1	2	3	4	5	6	7	8	9	10				
Alkaline soil treated with charcoal	44	33	30	44	29	22	35	34	31	29	331	33.1	44	22
Control Field	26	30	30	34	36	34	23	33	32	24	302	30.2	36	23

Kharif 2007	Narasimha Reddy	Narasimha Reddy Control	Venkataiah	Venkataiah Control	Janardhan Reddy	Janardhan Reddy Control
Crop	Paddy	Paddy	Paddy	Paddy	Cotton	Cotton
	(Sy.No. 23)		(Sy.No. 311/3)			
Soil type	Alkaline	Alkaline	Alkaline	Alkaline	Alkaline	Alkaline
Area sown (in acres)	Half	half	half	half	half	half
Seed variety	BPT 5204	BPT 5204	BPT 5204	BPT 5204	Hima –BT (Cotton)	Hima - BT (Cotton)
Inputs						
Charcoal	750 kg.		750 kg.		750 kg.	
DAP	DAP – 1 bag	DAP – 1 bag	DAP – 1 bag	DAP – 1 bag	DAP – 1 bag	DAP – 1 bag
Urea	UREA – 1 bag	UREA – 1 bag	UREA – 1 bag	UREA – 1 bag	UREA – 1 bag	UREA – 1 bag
Gypsum	100 kgs		100 kgs		100 kgs	
Sand	5 tractors		5 tractors		5 tractors	
Zinc	10 kg.		10 kg.		10 kg.	
Farm Yard Manure	1 ton	1 ton	1 ton	1 ton		
Potash	5 kg.		5 kg.		5 kg.	

Bio-fertilizers – soil microbes						
Azotobactor	1. Azoto Bactor – ½ kg		1. Azoto Bactor – ½ kg		1. Azoto Bactor – ½ kg	
Tricoderma	2. Tricoderma – ½ kg		2. Tricoderma – ½ kg		2. Tricoderma – ½ kg	

Azospirillum	3. Azospirillum – ½ kg		3. Azospirillum – ½ kg		3. Azospirillum – ½ kg	
Pseudomonas	4. Pseudomonas – ½ kg		4. Pseudomonas – ½ kg		4. Pseudomonas – ½ kg	
Water source	Filter wells	Filter wells	Bore well	Bore well	Rainfall	Rainfall
No. of irrigations	45	45	48	48		1
Practice - SRI	Yes	Yes	Yes	Yes	Cotton	
Pests	Blight	Blight	Stem boarer	Stem boarer	Leaf Coald	Leaf Coald
Pesticides application chemical						
IPM / NPM	Neem Oil	Neem Oil	Pheromone traps	Pheromone traps	Neem Oil	Neem Oil
Paddy Tillers	38 – 42	22 – 25	40-45	25 - 30		
Cotton bowls	NA	NA	NA	NA	15 - 20	6 to 12
Bags of paddy per acre	21 bags	12.5 bags	22.5 bags	12 bags	5 Qtls.	2.5 Qtls.
Income total	15,200/-	8,250/-	18,130/-	7,350/-	6,720/-	2,800/-
Remarks						

Rabi 2007

Rabi,2007	Narasimha Reddy Paddy	Control	Venkataiah	Control
Crop	Paddy	Paddy	Paddy	Paddy
	(Sy.No. 23)		(Sy.No. 311/3)	
Soil type	Alkaline soil	Alkaline soil	Alkaline soil	Alkaline soil
Area sown	half	half	half	Half
Seed variety	IR-64	IR-64	IR-64	IR-64
Inputs				
Charcoal				
DAP	50 kgs	50 kgs	50 kgs	50 kgs
Urea	50 kgs	50 kgs	50 kgs	50 kgs
Gypsum	300 kgs	300 kgs	300 kgs	300 kgs
Sand				
Zinc				
FYM	½ ton	½ ton	½ ton	½ ton
Potash				
NPM				
Biofertilizers – soil microbes				

1. Azoto Bactor	-	-	-	-
2. Tricoderma				
3. Azospirillum				
4. Pseudomonas	-	-	-	-
Water source	Filter well	Filter well	Bore well	Bore well
No. of irrigations	50	50	49	49
Practice - SRI	SRI	SRI	SRI	SRI
Pests	Stem borer	Stem borer	-	-
Pesticides application chemical				
IPM / NPM	Neem Oil	Neem Oil	Vitex	Vitex
Paddy Tillers	48 - 50	25 – 30	44 - 46	25 – 28
Bags of paddy	24.5 bags	14 bags	21 bags	13.5 bags
Income	21,250/-	9,800/-	18,230/-	10,300/-
Remarks				

From the above tables it is clear that there is increase in production of the yield as compared to the control fields of the same farmers. The farmers are happy to see the results after application of charcoal plus amendments.

 Testing the soil texture by walking bare foot in the paddy field	 Mixing the manure, charcoal and the soil microbes	 Charcoal and sand after application in the field
 Comparison of the paddy with soil amendments (left) and without charcoal (right)	 Counting tillers in a Paddy Field with soil amendments	 Alkaline soil white in color

Case Study of Mr. Narasimha Reddy

Mr. Narasimha Reddy, a progressive farmer is having about three acres of land. Of which, one acre land consists of highly alkaline soil, in which there is no possibility to cultivate crops profitably. The farmer in the past observed that 70% of the Paddy seeds sown have not germinated.

When Dr. Reddy, explained the farmers about the possibility of reclamation of alkaline soils, Mr. Narasimha Reddy has come forward to try the methodology suggested in half an acre of land which was left fallow. Because of ubiquitous Prosopis Juliflora and the charcoal making activity going on in Kothur Village, the quantity of charcoal required was not a problem. Similarly because of the Dundubi stream flowing adjacent to the village, there is plenty of sand available in it.

Mr. Narsimha Reddy has chosen SRI Paddy cultivation in this half acre land. He could get 80% of the crop because of the soil amendments carried out as compared to the regular fields adjoining. The farmer was very happy as he could get good yield and also able to reclaim his other wise fallow land. He could get 16 bags of Paddy from his half acre land, where hardly he was getting

5-6 bags earlier. In the future the farmer has plans to adopt similar methodology to reclaim half acre of remaining fallow land with alkaline soils. He also said that many farmers from his own and neighboring villages have visited his field and they were also willing to take up the charcoal plus soil amendment activity in their respective lands with alkaline soils and reclaim them. Villagers want to eradicate Prosopis Juliflora from their fallow lands and reclaim them for cultivation with similar practice in the near future.

Mr. Narasimha Reddy having adopted the soil amendment practice is now a model farmer in the state, he is sharing his experience by participating in the seminars and workshops organized for farmers at various levels.

6. DISCUSSIONS

Alkaline soils are difficult to take into agricultural production. Due to the low infiltration capacity, rain water stagnates on the soil easily and, in dry periods, irrigation is hardly possible. Agriculture is limited to crops tolerant to surface water logging (e.g. rice, grasses) and the productivity is low.

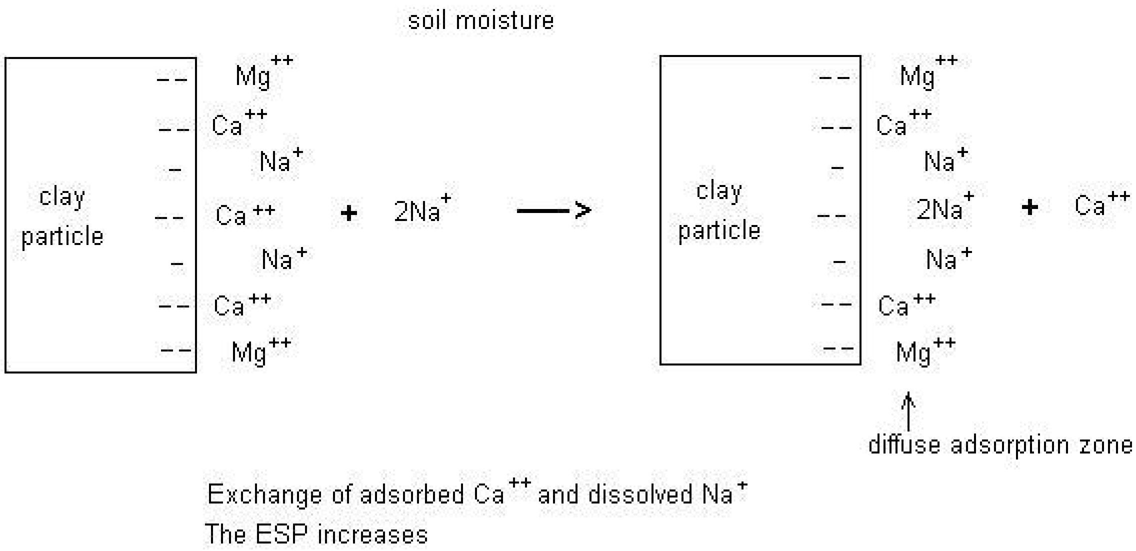
Reasons for soil alkalinity is associated with the presence of sodium carbonates or (soda) (Na_2CO_3) in the soil, either as a result of natural weathering of the soil particles or brought in by irrigation and/or flood water. The sodium carbonate, when dissolved in water, dissociates into $2Na^+$ (two sodium cations, i.e. ions with a positive electric charge) and $CO_3^{=}$ (a carbonate anion, i.e. an ion with a double negative electric charge).
The sodium-carbonate can react with water to produce carbon dioxide (CO_2), escaping as a gas, and sodium hydroxide (Na^+OH^-), which is alkaline (or rather basic) and gives high pH values (pH>9).

The reaction between Na_2CO_3 and H+O can be represented as follows:

$$2Na^+ + CO_3^{--} + 2H^+ + 2OH^- \rightarrow 2Na^+ + 2OH^- + H_2CO_3$$

The acid H_2CO_3 is unstable and produces H_2O (water) and CO_2 (carbon dioxide gas, escaping into the atmosphere). This explains the remaining alkalinity (or rather basicity) in the form of soluble sodium hydroxide and the high pH. Not all sodium carbonate follows the above chemical reaction. The remaining sodium carbonate, and hence the presence of $CO_3^{=}$ ions, causes $CaCO_3$ (which is only slightly soluble) to precipitate as solid calcium carbonate (limestone). Hence, the calcium ions Ca^{++} are immobilized:

$$2Na^+ + CO_3^{=} + Ca^{++} \rightarrow 2Na^+ + CaCO_3 \text{ (solid)}$$



Sodium exchange process

The presence of abundant Na+ ions in the soil solution and the precipitation of Ca++ ions as a solid mineral causes the clay particles, which have negative electric charges along their surfaces, to adsorb more Na+ in the diffuse adsorption zone (DAZ, see figure) and, in exchange, release Ca++, by which their exchangeable sodium percentage (ESP) is increased as illustrated in the figure:

Na+ is more mobile and has a smaller electric charge than Ca++ so that the thickness of the DAZ increases as more sodium is present. The thickness is also influenced by the total concentration of ions in the soil moisture in the sense that higher concentrations cause the DAZ zone to shrink.

Clay particles with considerable ESP (> 16), in contact with non-saline soil moisture have an expanded DAZ zone and the soil swells (dispersion). The phenomenon results in deterioration of the soil structure, and especially crust formation and compaction of the top layer. Hence the infiltration capacity of the soil and the water availability in the soil is reduced, whereas the surface-water-logging or runoff is increased. Seedling emergence and crop production are badly affected. Under saline conditions, the many ions in the soil solution counteract the swelling of the soil, so that saline soils usually do not have unfavorable physical properties. Alkaline soils, in principle, are not saline since the alkalinity problem is worse as the salinity is less.

Alkalinity problems are more pronounced in clay soils than in loamy, silty or sandy soils. The clay soils containing montmorillonite or smectite (swelling clays) are more subject to alkalinity problems than illite or kaolinite clay soils. The reason is that the former types of clay have larger specific surface areas (i.e. the surface area of the soil particles divided by their volume) and higher cation exchange capacity (CEC).

Certain clay minerals with 100% ESP (i.e. fully sodium saturated) are called bentonite, which is used in civil engineering to place impermeable curtains in the soil, e.g. below dams, to prevent seepage of water.

The majority of food crops prefer a neutral or slightly acidic soil.

	Acid						**Neutral**						Alkaline
	4	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**	**10.5**
nitrogen, **N**													
phosphorus, **P**													
potassium, **K**													
calcium, **Ca**													
magnesium, **Mg**													
sulphur, **S**													
iron, **Fe**													
manganese, **Mn**													
boron, **B**													
copper, **Cu**													
zinc, **Zn**													
molybdenum, **Mo**													

The above table gives a guide to the availability of several nutrients at various pH values

More frequent irrigations become necessary to keep up with increasing soil alkalinity levels. Plants are most sensitive to alkaline soils during germination. Once established, they have the ability to tolerate higher soil alkalinity levels. Leaching and/or drainage has to be established to flush the salt levels below the root zone. Managing alkaline soil pH is best done by maintaining high levels of free calcium in the soil. This is why gypsum is added to soils with high soil pH (>8.0). Gypsum is an excellent and inexpensive source of soluble calcium. The soluble calcium removes the carbonate from the soil by forming limestone.

7. SUGGESTIONS AND RECOMMENDATIONS

- The percentage of alkaline soils are increasing due to climate variability / change in the semi-arid parts, there is a need to reclaim them and the practice adopted in Kothur village is one such latest practice.
- There is considerable increase in yield of the crops like paddy and cotton produced with application of charcoal and plus amendments made to the alkaline soils, which were otherwise would have been left fallow.
- The farmers' livelihoods can be made sustainable through reclamation of the fallow or less fertile lands through adoption of such methodology.
- There is a need to fine tune the methodology through scientific field trials conducted.
- The charcoal can be generated from the wasted biomass like crop residue, weeds like Prosopis Juliflora, etc.
- The carbon sequestration is addressed through application of charcoal in the soil, and the process in turn helps in production of more biomass.

8. REFERENCES

- http://www.biochar-international.org/
- http://www.geo.uni-bayreuth.de/bodenkunde/terra_preta/index.html
- http://www.css.cornell.edu/faculty/lehmann/index.htm
- http://charboncapture.org/
- http://e-alkalinesoilsterrapreta.blogspot.com/
  http://www.shimbir.demon.co.uk/biocharrefs.htm
- http://e-terrapreta.blogspot.com/
- http://terrapreta.bioenergylists.org/
- http://e-terrapretarooftopexp.blogspot.com/
- http://en.wikipedia.org/wiki/Soil_pH
- http://harristurf.crinet.com/education_train/pdfs/alkaline_soil.pdf
- http://en.wikipedia.org/wiki/Terra_preta

- R.Brinkman, 1988. Saline and sodic soils. In: Land Reclamation and Water Management, ILRI publication 27, p.62-68, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. ISBN 90 70 26062 1
- http://www.ars.usda.gov/Services/docs.htm?docid=10158 US Salinity Lab Handbook 60 G.H.Bolt (ed.), 1981. Soil chemistry: A. basic elements. Vol 5a, Elsevier, Amsterdam, The Netherlands
- Chhabra, R. 1996. Soil Salinity and Water Quality. pp 284. Oxford&IBH Publishing Co. Pvt. Ltd., New Delhi (South Asian edition) and A.A. Balkema Uitgevers BC, Rotterdam (edition elsewhere). ISBN 81 204 1049 1.

Study was done by: Dr. N. Sai Bhaskar Reddy, CEO, GEO