Role of Compost and Bio-fertilizers in Saline Soils Mitigation

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Presentation Outline

- Background of Mehran University Water Center
- Introduction to Soil Salinity and its Treatment Methods
- Introduction to Compost and Bio-fertilizers and their properties
- Global data on Applications of Composting and Bio-fertilizers on Saline Soils Mitigation
- Combined Application of Chemical and Composting on Saline Soils

Background Water Center

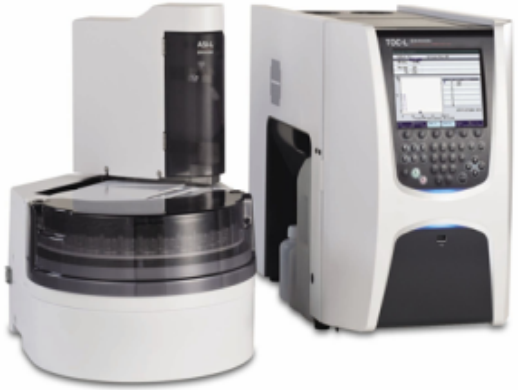
- U.S.-Pakistan Center for Advanced Studies in Water (USPCAS-W) has been established at Mehran University of Engineering and Technology, Jamshoro under USAID Funding for 5 years (From December 2015 to 2019).
- Now USPCASW is a national water center and part of Mehran University, Jamshoro
- USPCAS-W is dedicated to applied research on water and related sectors i.e. Agriculture, health and energy.

Background Water Center

Sindh Environmental Protection Agency Acredited Laboratories for Testing of Water, Air, Soil, Chemicals, Fertilizers

ICP-MS

LC-MS



TOC/TN Analyzer

Spectrometer

HP-IC

Q-PCR

Soil Salinity and Its Challenges

Challenges in Agriculture Sector

- Around 6.3 Million Hectares Saline and Degraded lands; around 2.5-3 Million Hectares in Sindh[1 & 2]
- Heavy reliance on Chemical Fertilizers
- Estimated 273 Million Tons of Waste Biomass per annum[2]
- Water shortage and poor quality
- Agriculture Biomass open Burning/Decomposition; CO_2 Emissions, loss of organic matter and soil moisture

[1] Environmental and Social Management Framework Transforming the Indus Basin with Climate Resilient Agriculture and Water Management FAO - UN Report, 2018

[2] Dr. Alim Mian et. al. 'Pakistan's Soil Resources' 1993 by IUCN – The World Conservation Union, Pakistan

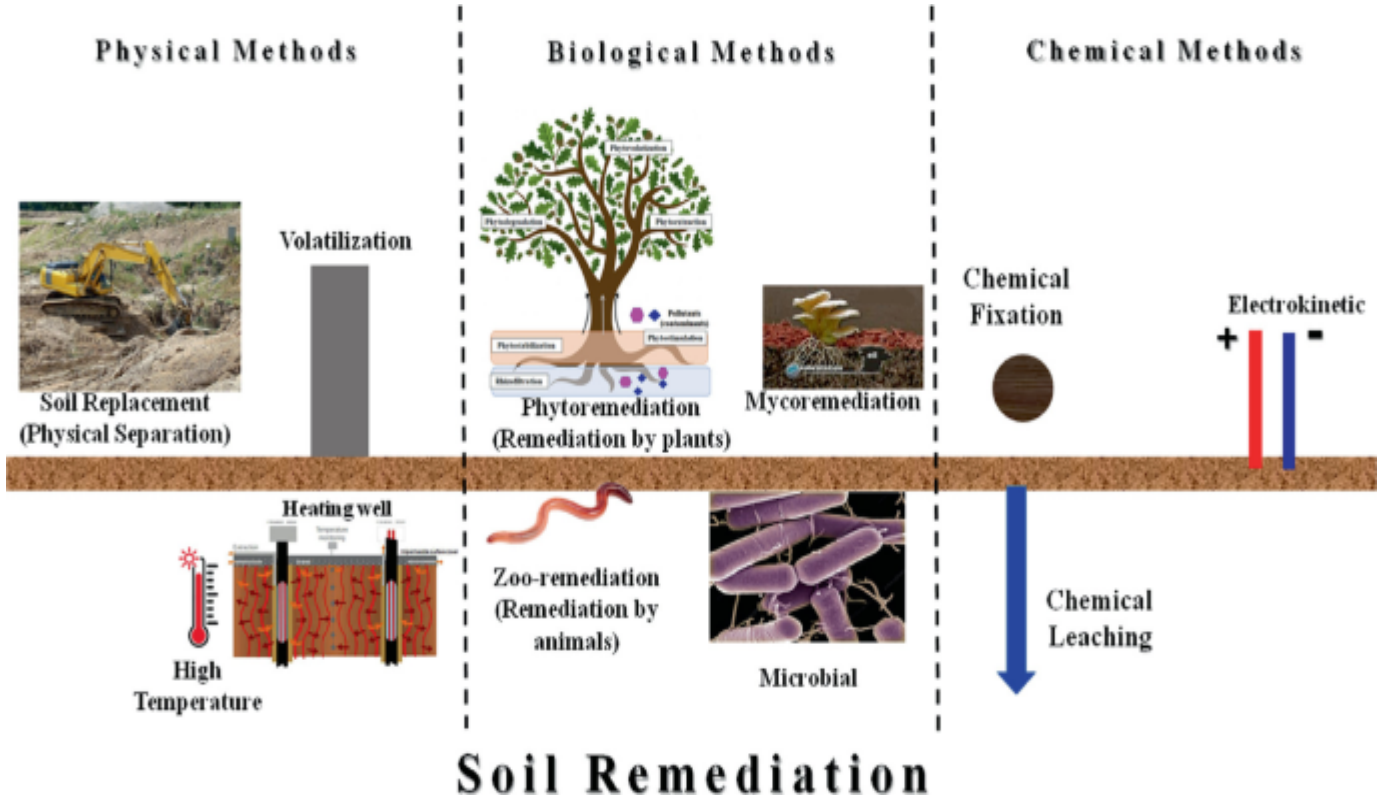
[3] Saeed, MA, Irshad, A, Sattar, H et al; http://dx.doi.org/10.5071/IBSCE2015-1CO.1.2

Introduction to Soil Salinity

- Soil salinity is the excessive accumulation of soluble salts, mainly sodium, chloride, calcium, and magnesium, that negatively impact plant growth. Signs of High Electric Conductivity (≥4 ds/m), High pH (≥ 8), High Sodium Adsorption Ratio SAR (≥ 13)
- **Main Causes:**
  - Natural (parent rock weathering, groundwater intrusion, groundwater quality).
  - Human-induced (excessive irrigation, poor drainage, chemical fertilizer overuse).
  - Climate change factors: Rising temperatures & reduced rainfall increase salinity risks.
- **Impact on Agriculture:**
  - Reduced seed germination and plant growth.
  - Altered soil structure leading to compaction and poor aeration, stunted growth.
- Decreased crop productivity and economic losses.

Various Treatment Options for Saline Soil

- **Physical methods:** Deep plowing, sub-soiling, leaching with fresh water.
- **Chemical amendments:** Use of gypsum, sulfur, Acids
- **Biological methods:** Composting, biofertilizers, salt-tolerant crops, microbial remediation.
- **Integrated approaches:** Combining physical, chemical, and biological strategies.



Introduction to Composting

- Composting is the controlled biological decomposition of organic matter into nutrient-rich humus.
- **Types of composting:** Aerobic, anaerobic, vermicomposting.
- **Benefits:** Enhances soil structure, increases water retention, promotes microbial activity.

Compost and Biofertilizers Properties

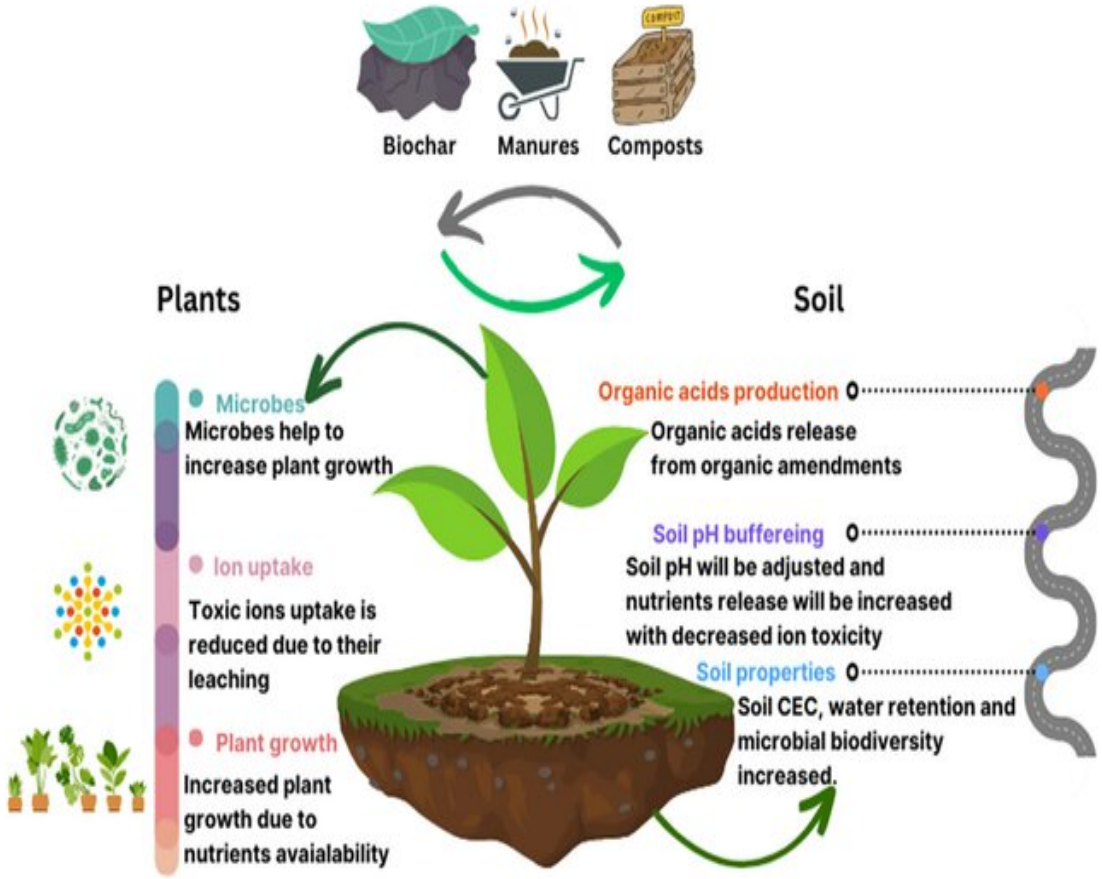
Property	Description
Organic Matter (%)	40–60% (Improves soil structure and fertility)
Moisture Content (%)	30–50% (Essential for microbial activity)
pH	6.5–8.0 (Neutral to slightly alkaline, stabilizes soil pH)
Electrical Conductivity (dS/m)	1.5–4.5 (Indicates salt content, should be moderate)
C/N Ratio	15:1 to 25:1 (Ideal for nutrient balance and microbial activity)
Nitrogen (N) (%)	0.5–3% (Essential for plant growth and soil fertility)
Phosphorus (P_2O_5) (%)	0.2–1.5% (Supports root development)
Potassium (K_2O) (%)	0.5–2.5% (Enhances plant disease resistance and growth)
Calcium (Ca) (%)	1–3% (Improves soil structure and neutralizes acidity)
Magnesium (Mg) (%)	0.2–1.2% (Essential for chlorophyll production)
Microbial Population	High
Water Retention Capacity	High (Enhances soil moisture-holding ability)

Introduction to Biofertilizers

- Biofertilizers contain value-added compost with beneficial microorganisms that enhance soil fertility.
- **Types of biofertilizers:**
  - Nitrogen-fixing bacteria (Rhizobium, Azotobacter).
  - Phosphate-solubilizing bacteria (Pseudomonas, Bacillus).
  - Potassium-mobilizing bacteria (Frateuria aurantia).
- Mycorrhizal fungi (Glomus species).

Properties of Compost Fertilizers for Saline Soil

- High organic matter reduces bulk density and improves aeration.
- Contains humic acids that bind excess salts, preventing plant uptake.
- Promotes beneficial microbes that break down toxic salts.
- Enhances water-holding capacity, reducing irrigation needs.



Composting as a Biochemical Treatment

- **Reported Studies:**
  - A study in India showed **20% increased wheat yield** in compost-amended saline soil.
- Compost improved **soil electrical conductivity (EC) from 6.5 to 3.1 dS/m** in a study from China.
- **Reported Studies:**
  - A Pakistani study showed that inoculation with **Azospirillum** increased **rice yield by 30%** in saline conditions.
  - **Biofertilizers reduced Na+ ion toxicity by 40%** in Egyptian saline soils.

Treatment Comparison

Treatment Method	Effectiveness	Cost	Sustainability	Implementation Difficulty
Compost & Biofertilizers	High	Medium	High	Easy
Gypsum	High	Medium	Medium	Moderate
Acid Leaching	High	High	Low	Difficult

- Compost and biofertilizers show gradual improvement over time.
- Gypsum rapidly reduces EC but requires proper water drainage.
- Acid leaching results in a sharp decline in EC but poses environmental risks.

Our Work on Composting and Its Applications

Waste Biomass Feedstock

- Agricultural Waste (Banana, Rice residues, Cotton stalks, Sugarcane residues)
- Wood Biomass (wild Acacia, Eucalyptus, Prosopis)
- Livestock Animal Manure

Feedstock Amount and Fertilizers Production Potential

Estimated **40 % readiness** of waste biomass for Bio-Fertilizers Production

Summary of Agricultural Waste Resources in Pakistan [4-7]

Waste Biomass Type	Quantity (1000 tons) /year	Potential Fertilizer Production (1000 tons)/year
Cotton	24,000	9600
Wheat	34,890	14000
Rice	8300	3300
Maize	180	70
Sugar cane	16,830	6700
Livestock Dung	32000	9500
Millet Husk cobs	880	350
Sunflower	222	90
Banana waste	2075	830

[4] *E. Lichtfouse (ed.), Sustainable Agriculture Reviews, Sustainable Agriculture Reviews 22, DOI 10.1007/978-3-319-48006-0_4*
[5] *Mahar, R.B. et. al. Biomethanization potential of waste agricultural Biomass in Pakistan: a case study. International Journal of biomass and renewables, 1(1)*
[6] *Saeed, MA, Irshad, A, Sattar, H et al; http://dx.doi.org/10.5071/IBSCE2015-1CO.1.2*
[7] Land Utilization Statistics, 2014, Pakistan Bureau of Statistics

Potential Solutions

Solid Bio-fertilizer

Liquid Bio-fertilizer

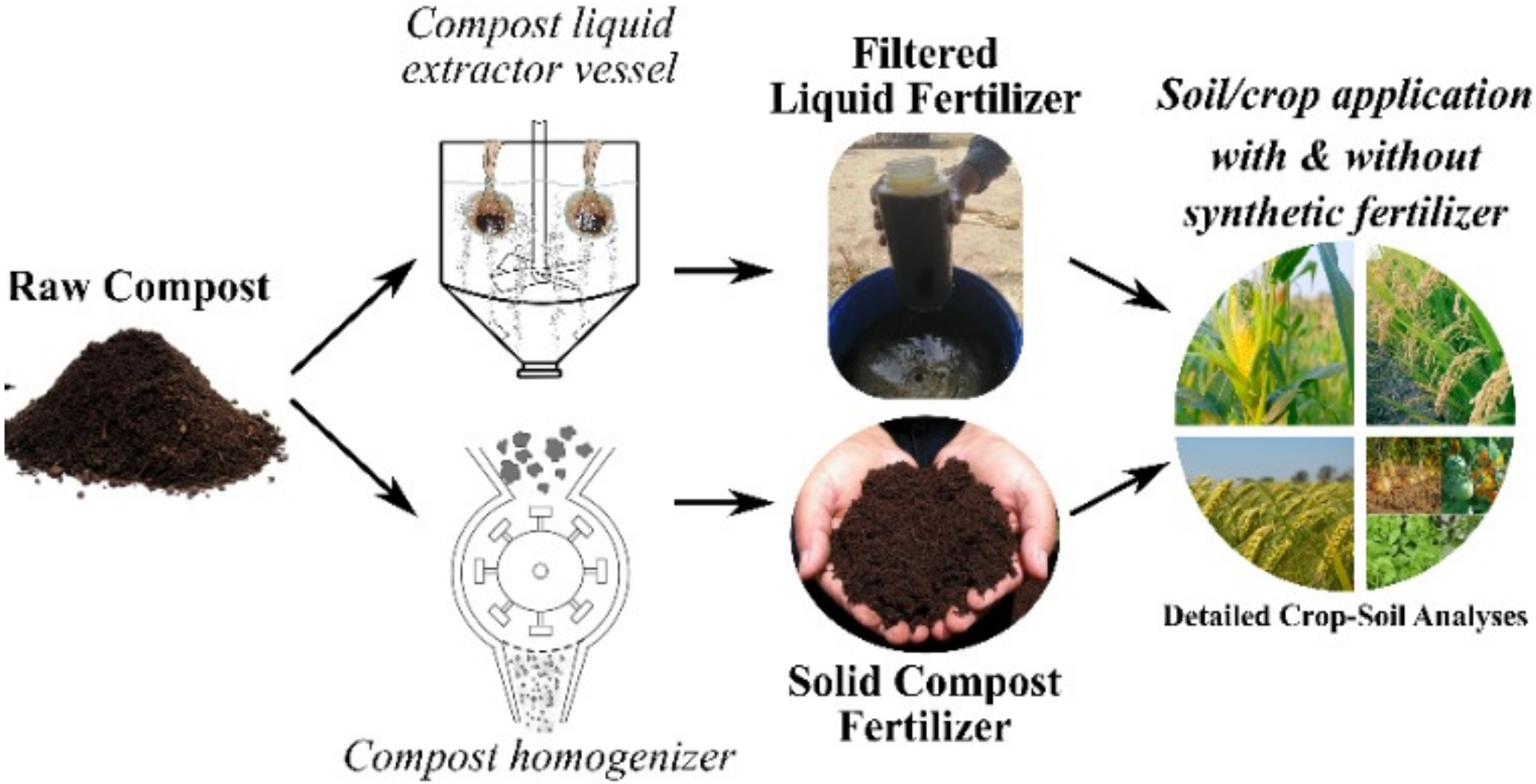
Biochar

Process of Conversion Biomass into Compost Fertilizers




Waste Biomass Collection, Pre-Grinding/Shredding, Shifting into Decomposition Vessels, Multiple Turnings, Post-Grinding, Sieving and Pelletization; Avg. Conversion Cycle 25-35 days

Process of Conversion Biomass into Liquid Fertilizers



Field Results (Cotton)

Cultivation of Cotton on Solid and Liquid Fertilizers combined applications @ half of the cost/acre compared to conventional fertilizers

Field Results (Wheat)




Cultivation of Wheat on Solid and Liquid Fertilizers combined applications @ 40% reduced cost/acre compared to conventional fertilizers

Field Results (Chilies)

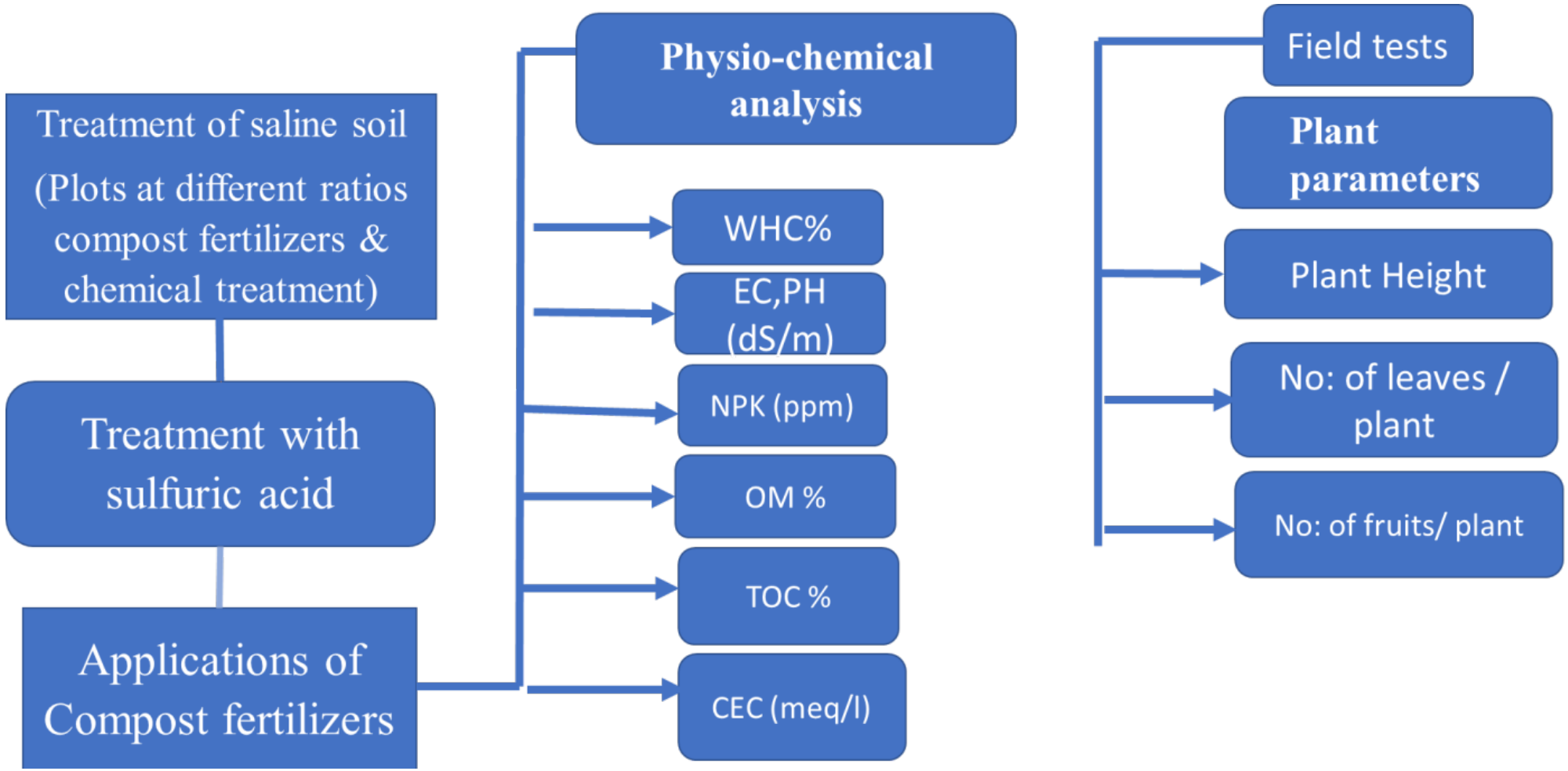
Before and after Liquid fertilizer Spray

With more pest & virus free yield than conventional methods

Field Results (Okra)

Okra before and after Liquid fertilizer Spray
With 50% more yield than conventional methods

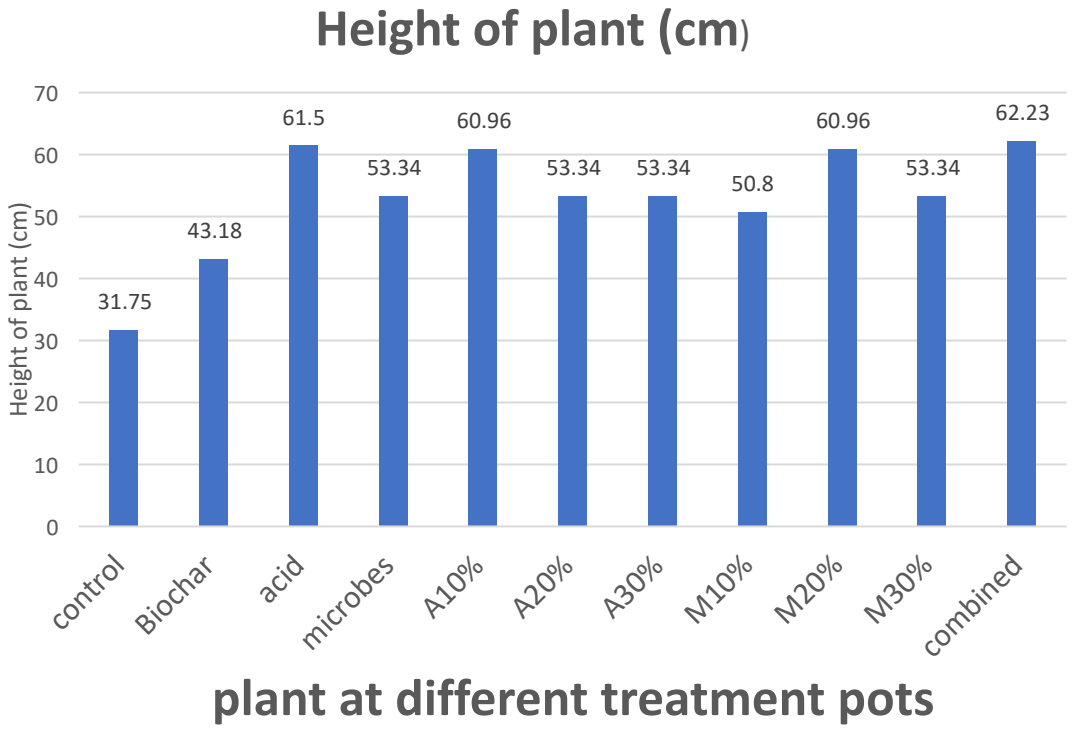
Combined Chemical and Compost Fertilizer Treatment

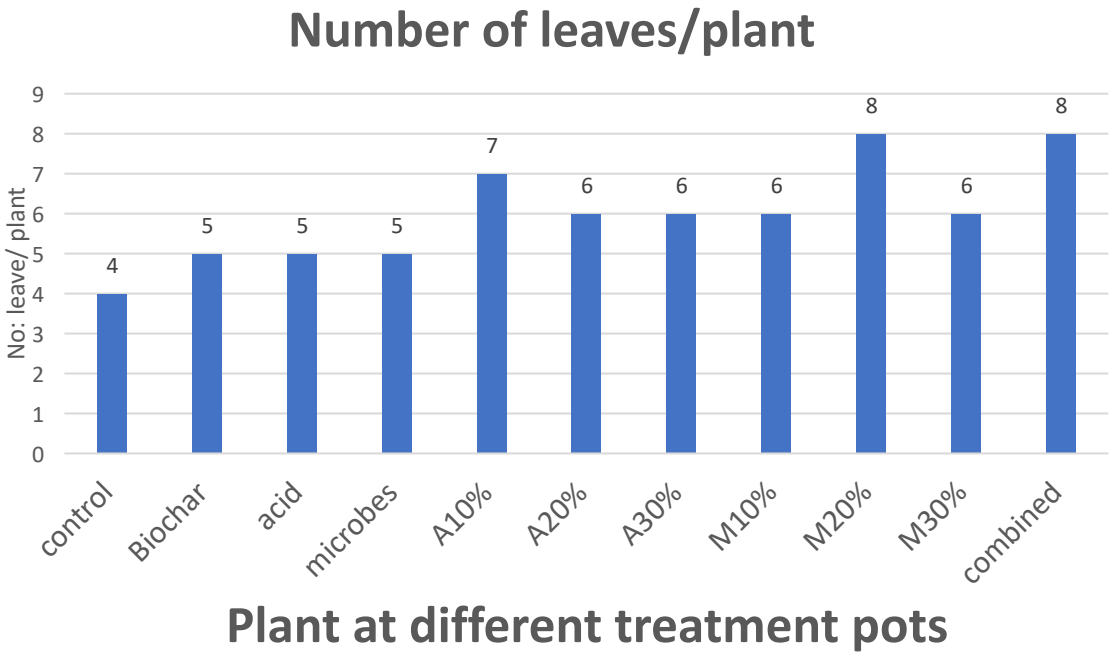


Combined Chemical and Compost Fertilizer Treatment

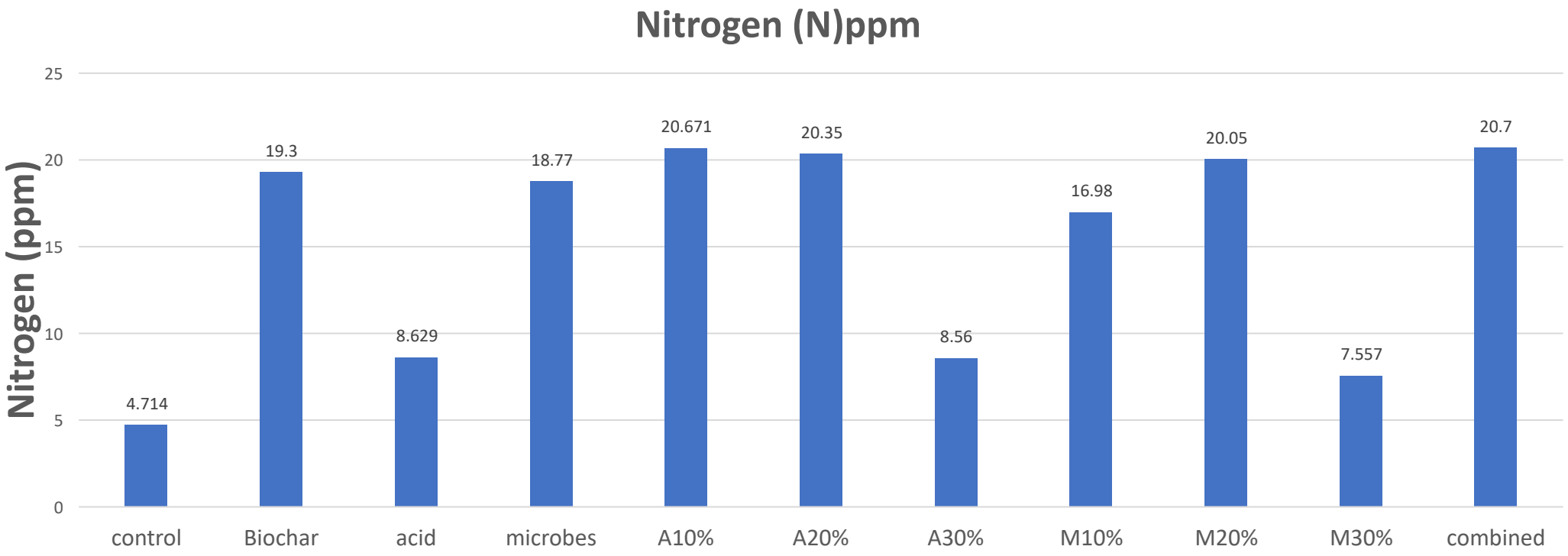
Number of pots	Treatment	Rate of application/pot	Soil treatment ratio
1	Control (only soil)	0	100%soil
2	Compost (only)	1	40% Compost Fertilizer +60% soil
3	Acid (0nly)	1	40% of acid and soil
4	Microbes (only)	1	40% of microbes and soil
5	Compost Fertilizer+10%acid	1	10% Compost Fertilizer+90% soil
6	Compost Fertilizer+20%acid	1	20% Compost Fertilizer+80% soil
7	Compost Fertilizer+30%acid	1	30% Compost Fertilizer +70% soil
8	Compost Fertilizer+10%microbes	1	10% Compost Fertilizer+ 90% soil
9	Compost Fertilizer+20%microbes	1	20% Compost Fertilizer+80% soil
10	Compost Fertilizer+30%microbes	1	30% Compost Fertilizer+70% soil
11	Compost Fertilizer + microbes + acid	1	30% Compost Fertilizer+20% microbes+ 10% acid

Combined Chemical and Compost Fertilizer Treatment: Results

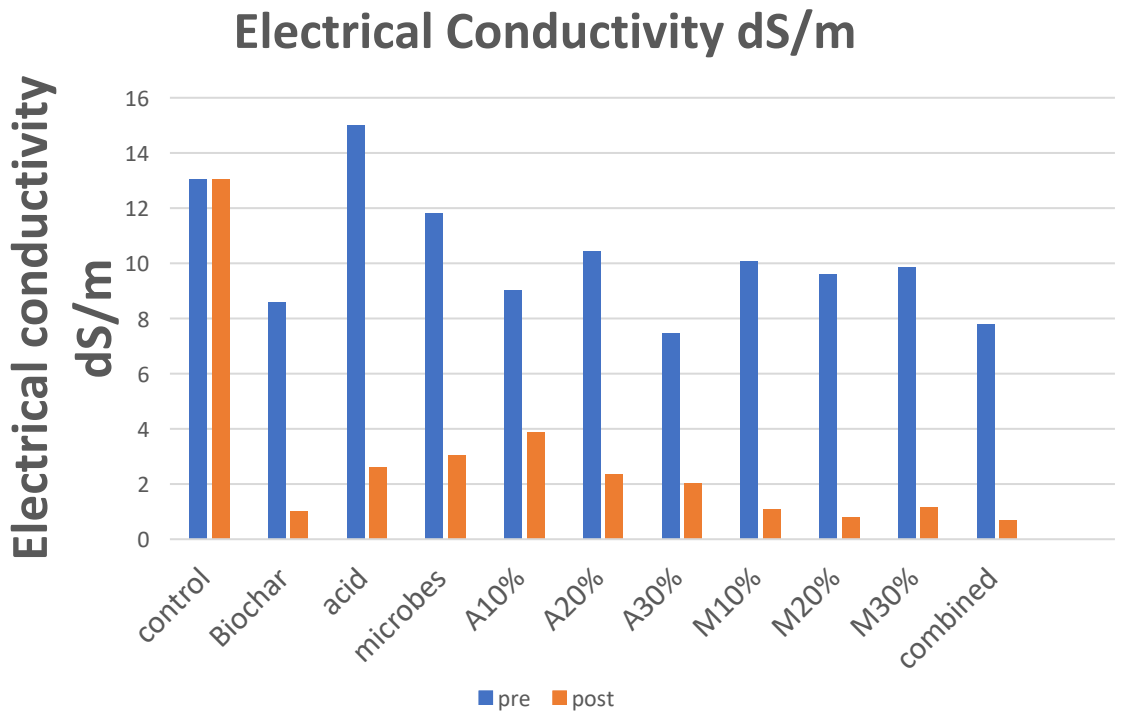




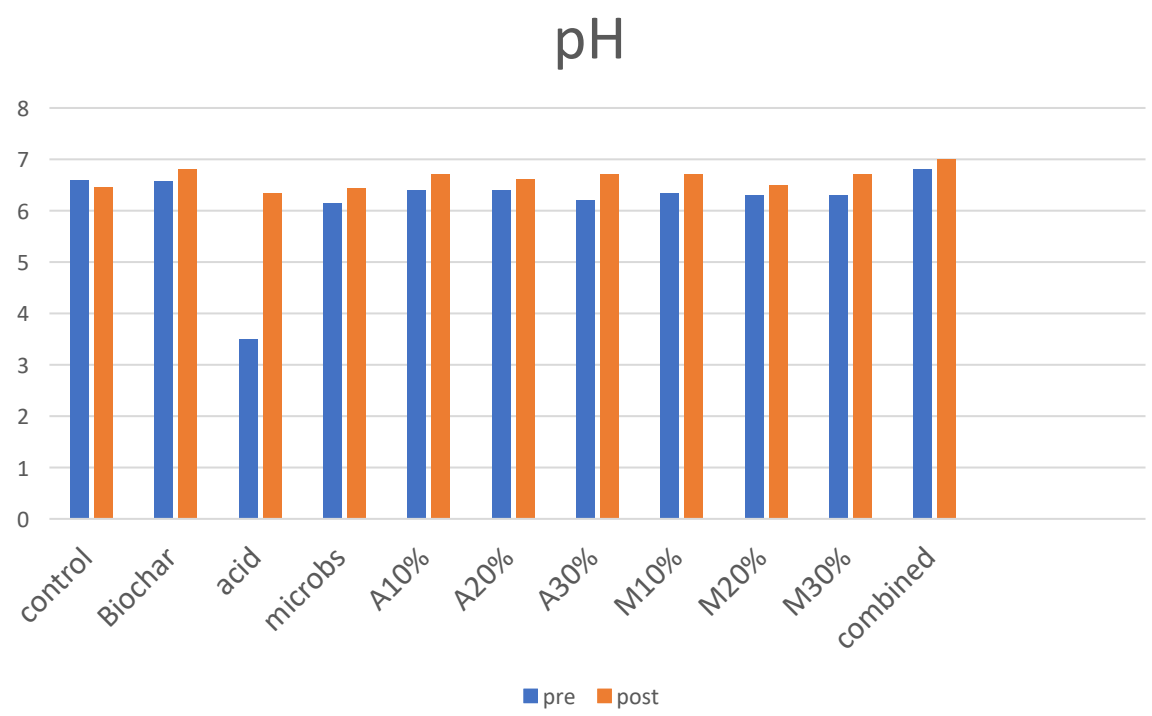
Combined Chemical and Compost Fertilizer Treatment: Results



Effect on saline soil after treatment soil

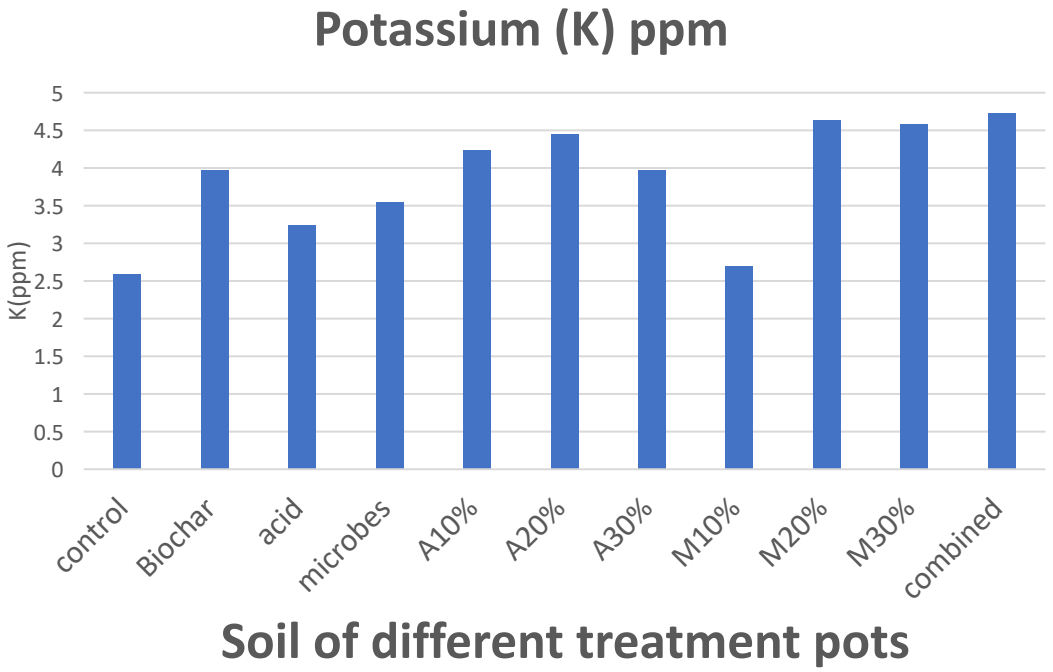


concentration of EC dS/m in different treatment pots

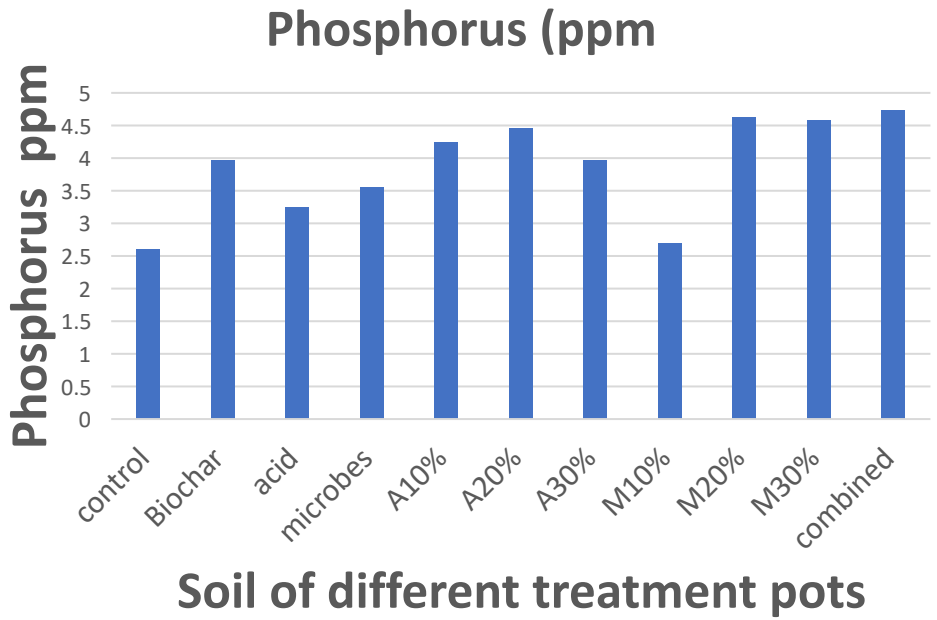


concentration of PH in different treatment pots

Combined Chemical and Compost Fertilizer Treatment: Results

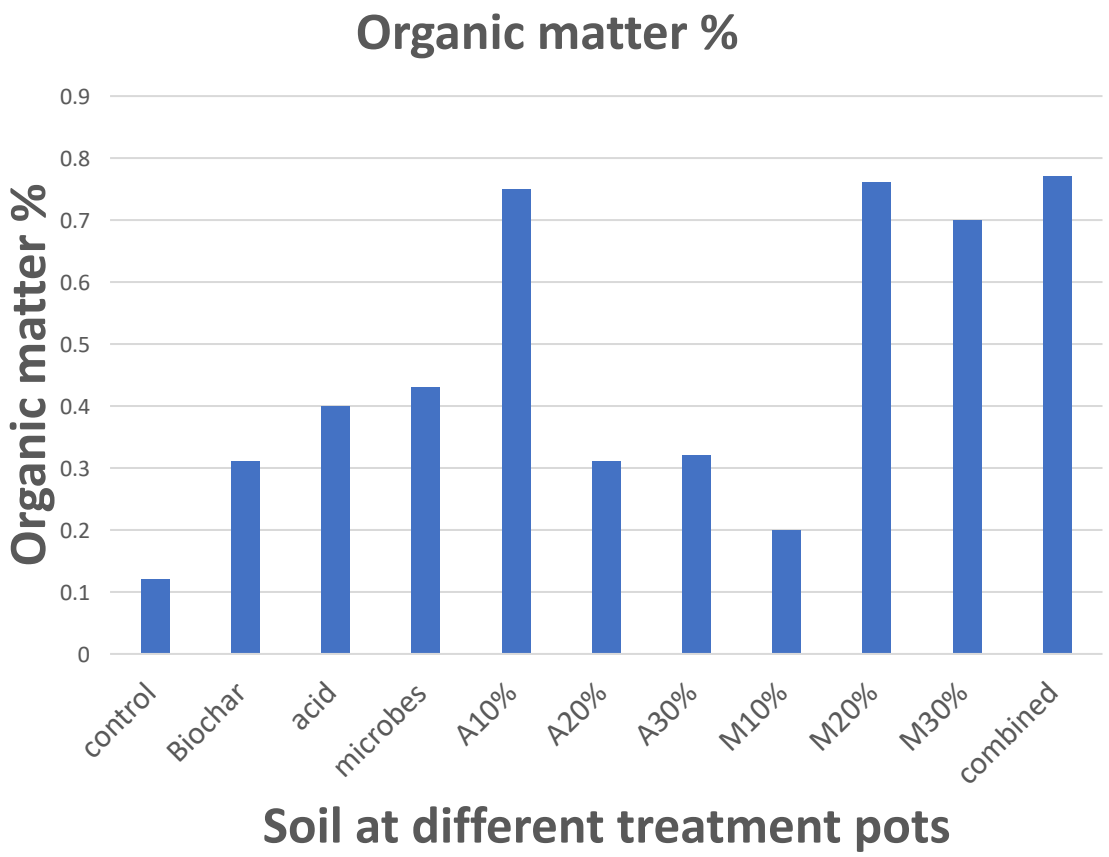


concentration of potassium (K) ppm at different treatment pots

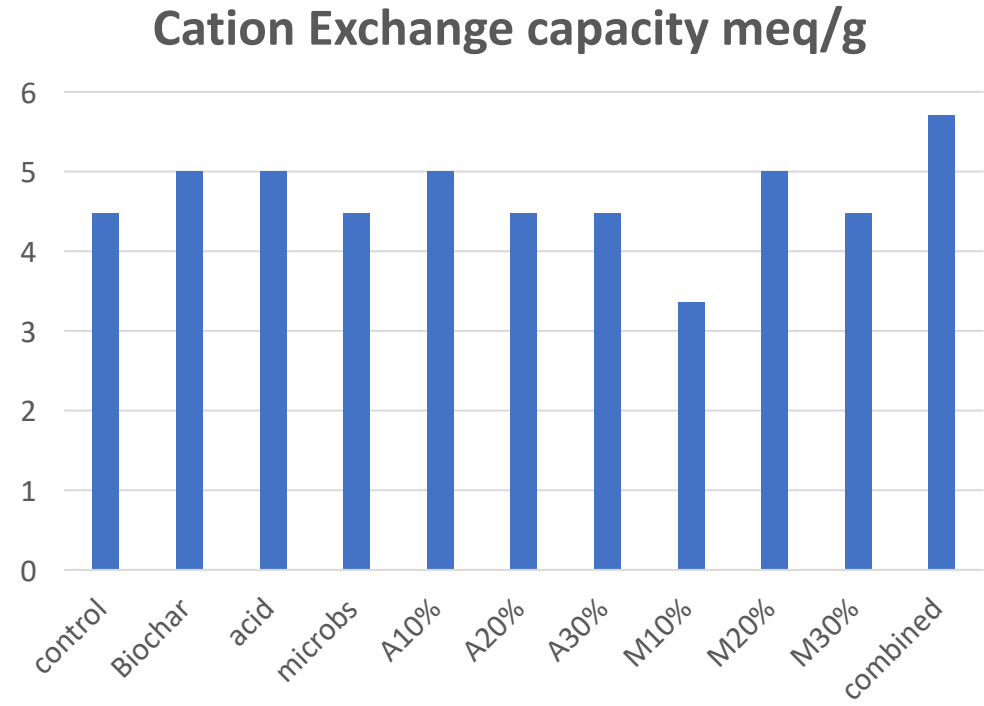


concentration of phosphorus (P) ppm at different treatment pots

Combined Chemical and Compost Fertilizer Treatment: Results



organic matter at different treatment pots



cation exchange capacity meq/g of different treatment pots

Combined Chemical and Compost Fertilizer Treatment: Results

Soil Parameters	Saline Soil before treatment	Soil after treatment of Acid and Compost fertilizer applications
pH	The PH of saline soil before the treatment was 7.8.	The PH of saline soil after the treatment of which is 7.6.
EC dS/m	The Electrical conductivity of saline soil was 13.03 dS/m.	The electrical conductivity of soil after treatment is 2.90 dS/m
OM %	The Organic matter of soil before the treatment was observed 0.16.	The organic matter after the treatment of e soil 0.77.
WHC %	The water holding capacity of soil before the treatment was 34%.	The water holding capacity of soil after treatment in 52%.

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Thanks for Your kind attention!