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Original Research Article

Assessment of Soil Health after Amelioration of a Degraded Soil - A New Dynamic Approach

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Keywords

Amendments, Soil health, SHEI index, Physico-chemical properties, Degraded soil

A B S T R A C T

A pot culture experiment was carried out on degraded soil of ravine lands to assess the amendments effects on soil health. Thirteen treatments were consisted of ameliorants with two doses of gypsum viz @ 1 and 2 t ha^{-1}, cluster bean straw @ 20 t ha^{-1}, biochar @ 10t ha^{-1}, distillery spent wash (DSW) @ 5 Lac L ha^{-1}, with their combinations and control laid out in completely randomized design (CRD) keeping three replications. The soil was ameliorated and incubated at field moisture content for two months to determine the changes in physico-chemical properties of soil. The results indicated that significantly ($P< 0.05$) lower bulk density, increased water holding capacity, porosity and hydraulic conductivity (k) in Gypsum + cluster bean straw + DSW. Aggregate (> 125µ) was higher in DSW @ 5 Lac L ha^{-1} which was at par with gypsum + cluster bean straw + DSW treatment. Highest EC, available N, P, K and organic carbon (OC) were recorded under gypsum + cluster bean straw + DSW treatment which was at par with gypsum + DSW. The overall improvement in soil physico-chemical properties and enhancing soil health was recorded under gypsum + cluster bean straw + DSW and was superior over other treatments. The soil health elevation index (SHEI) was found very effective to assess the improvement in soil health due to incorporation of various organic and inorganic ameliorants and it is very dynamic in nature to use with different soils.

Introduction

Soil health is a term which is widely used to describe condition of the soil resource. There are two ways in which the concept of soil health has been considered, which can be termed either ‘reductionist’ or ‘integrated’. The former is based on estimation of soil condition using a set of independent indicators of specific soil properties—physical, chemical and biological. This approach has been much discussed and well reviewed across the globe (Doran and Jones 1996; Van-Camp *et al.*, 2004). In reference to agriculture, soil quality has been defined as ‘‘the capacity of soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health’’ (Doran and Parkin, 1994). Typically, the concept of soil quality is considered to exceed the productivity of soils (Larson and Pierce, 1991; Parr *et al.*, 1992) to clearly include the interactions between humans and soil, and to include ecosystem sustainability as the basis for the benefits that humans derive from soils as well as the essential values of soil as being unique and distinctive (Carter *et al.*, 1997).

The term soil quality in this broader sense was already used by Warkentin and Fletcher (1977).

Compared to natural ecosystems, agricultural ecosystems undergo many disturbances and modifications and have many more nutrient inputs and outputs (Hendrix *et al.,* 1992; Magdoff *et al.*, 1997). Soil erosion associated with conventional tillage practices, degrades the receiving waters and the soil resource because of topsoil loss at the same time. While disturbance and soil modification during modern crop production are inevitable, there are ways to manage these disturbances to mimic natural systems, thereby reducing the adverse impact of agriculture on the environment. The levels of available plant nutrients, pH, salt content and organic matter (SOM) are important parameters of soil health. The biological, chemical, and physical aspects of soils all interact with and affect one another. Strategies for improving soil health requires a holistic approach that involves a long-term commitment to using combinations of practices that enhance the soil biological, chemical, and physical characteristics (Magdoff and Van Es, 2000). The primary strategies for improving soil health is addition of SOM through crop residues as well as animal manures and composts showed identical effects on soil properties. Continuous practices of composting not only enhance soil aggregation but also suppress soil borne crop diseases (Hoitink *et al.*, 1997). Crop residue on the soil surface protects the soil from moisture and temperature extremes and enhances rainfall infiltration, which provides more water for crops and at the same time reduces runoff and erosion.

Erosion decreases soil health by removing topsoil rich in organic matter. Management for improved soil quality does not focus on one strategy, such as reduced tillage or the use of cover crops. Combine use of many strategies are the key answer to improve soil quality. The addition of FYM and compost in soil decrease soil compaction, and improving nutrient management provides more benefits. Healthier soils have more diverse and active populations of soil organisms. Assessment and regular monitoring of soil health provide opportunity to evaluate land use management systems for sustainability of crop production and minimal environmental degradation (Manna *et al.,* 2013).

In India, ‘dryland ’feeds nearly half of country's population and contributes more than 40% of total food grain production. This region generally experiences low and uncertain returns, land degradation, frequent mid-season dry spells and water scarcity. Soils of these regions are thirsty and hungry, especially in secondary and macronutrients (NPK). The availability of nutrients is quite low in agricultural fields (marginal land) and Gullied (ravine) land and poor in soil physico-chemical properties. Appropriate land management practices that conserve soil and water coupled with integrated nutrient management, use of soil amendments and crop rotations would restore these stressed dryland soils (Somasundaram *et al.,* 2014).

There is hardly any historical record to show when the deterioration started, but it is reasonable to assume that indiscriminate use of land leading to disturbance of ecosystem has been one of the main causes for formation of ravines. Erratic, short duration and high intensity rainfall, erodible nature of soil, week geology of alluvium, steep slopes and overgrazing have combined to aggravate the situation. Ravine soil are sandy in texture, low in organic carbon and low to very low in nitrogen and phosphorus and physical degraded are very poor (Anonymous 2013). The water dispersible aggregates show that the soil of ravine/study area has very weak binding properties. Proper management of ravine soils can be converted into lush green agri-ecosystem, providing better food, fodder, fuel wood, fibre and medicinal crops/plants resulting into better socio-economic environment to the people of the ravines. The management of ravines soil and keeping these points in view the present study conducted to monitor the effect of soil amendment on soil health.

Materials and Methods

Location

For the present study Chambal ravine (26°30'N and longitude 78°04'E at about 177m MSL) soil was collected and incubated for two months at room temperature (25°C±20°C) soil science department, college of agriculture Gwalior (MP).

Experimental details

The experiment was conducted in earthen pots (medium size) of 20 kg weight, 35.56 cm height and 28.50 cm of diameter having polythene lined perforated water; total 39 pots were filled with 293 kg soil @ 7.5 kg pot^{-1}. The treatment pots were kept in laboratory at room temperature (28°C±32°C) and in absence of high gradient suction salt can not move to surface of pot. Thirteen treatments were consisted of ameliorants with two doses of gypsum viz @ 1 and 2 t ha^{-1}, cluster bean straw @ 20 t ha^{-1}, biochar @ 10 t ha^{-1}, distillery spent wash (DSW) @ 5 Lac L ha^{-1}, with their combinations and control. Bio-char is a fine-grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at high temperatures (~350–600°C) in an environment with little or no oxygen (Amonette and Joseph, 2009). Bio char is not a pure carbon, but rather mixer of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions (Masek, 2009).The amendments were applied to each pot as per treatment (Table, 2). The experiment was conducted in completely randomize (CRD) design with three replications (total 39 pots). The filled pots were incubated at field moisture content for two month to complete the soil reaction and decomposition. After the mixing of amendments in the soil it was necessary to irrigate the pot at particular level to keep it on field capacity moisture for two months till complete the process. After that soil was analysed for different physio-chemical properties.

Soil characteristics

Sampling and analysis

The plough layer soil (top 20 cm) collected from Chambal ravines of Morena district, India. Soil was sandy in texture, low in organic carbon (53 mg kg^{-1}) and low in nitrogen (180 kg ha^{-1}), phosphorus (4 kg ha^{-1}), potash (190 kg ha^{-1}); with poor soil physico-chemical properties i. e. WHC (21.7%), % porosity (40%), hydraulic conductivity (0.07 cm hr^{-1}), soil aggregates >125µ (25µ), pH (8.31) and EC (0.12 dS m^{-1}). The collected soil was incubated as per treatment (table. 2) for 2 months. After completion of incubation, soils were destructed, crushed and dried under shade, grounded in mortar with the help of pestle, sieved through sieve of size 2 mm and 0.5 mm and used for determination of physico-chemical properties

Soil physico-chemical properties

The physical properties including bulk density was determined by using small size core sampler (Blake and Hartge 1986), % porosity (Piper, 1966), soil aggregate stability was determined by wet sieving method, (Angers and Mehuys 1993), water holding capacity determined by Keen Raczkowski box technique, as described by Black (1965). The hydraulic conductivity (k) of a soil is a measure of the soil's ability to transmit water when submitted to a hydraulic gradient. Soil chemical properties such as soil pH and EC by Jackson (1967). Organic carbon (Walkley-Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al.,* 1954) and available potassium were determined (Jakson, 1967).

Assessment of elevation in soil health

A new parameter of Soil Health Elevation Index (SHEI) was computed from average percent enhancement in various parameters under consideration over control treatment on a unit basis.

Increasing favourable changes in percentage value of WHC, Porosity, Hydraulic conductivity, Soil Aggregates, EC, and OC over control were considered as positive changes, whereas unfavourable reductions over control in percentage value of BD and pH has been taken as positive being favourable for soil management and crop production. Mean was computed on the basis of the average of total percent of among the parameters which are divided by 100 for making out of scale is a good assessment for over all soil health changes.

SHEI =

$$\frac{\text{Total percent enhancement due to various factors under consideration}}{\text{Toatal number of parameters under consideration } \times 100}$$

SHEI was considered to be a very good in predicting soil health improvement due to application of various treatments. The positive value can be categorised as any changes <1.0 was considered as marginal changes, 1.0- 2.0 accepted as good, and >2.0 was excellent elevation/improvement

Organic and inorganic sources of soil amendments

Amendments for this study were chosen for reclamation of ravine soil to enhance their physico-chemical properties and maintain soil health. The harvested straw of cluster bean was used @80 g pot^{-1} which was equivalent to 20 t ha^{-1}; was obtained from, College of agriculture Gwalior research farm, having nutrient value N: 1.04%, P: 0.18 and K: 1.9%.

Biochar was obtained from the Gwalior coal depot Gwalior, (MP) and was applied @ 40 g/pot. It was equivalent to 10 t ha^{-1}. The post fermented distillery spent wash was collected from Gwalior Alcobrew Pvt. Ltd. (Bapuna Group) Rairu, Morena district of Madhya Pradesh, India The DSW was applied @ 2 L pot^{-1} as equivalent to 5 Lac L ha^{-1}. The detail characteristics of spent wash and Biochar were given in the Table 1. Commercial grade gypsum was used as a source of inorganic amendment as well as soil conditioner respectively in two different doses @ 1 t ha^{-1} and @ 2 t ha^{-1}

Statistical analysis

Data obtained were statistically analyzed with analysis of variance (ANOVA) in a CRD. The value was calculated only for those characters, which were found significant at 5 percent level of significance (*P = 0.05*). The null hypothesis was tested for organic and inorganic amendments and their combine effect on soil physico-chemical properties and available nutrient status.

The difference between the treatments means were tested for statistical significance by the Least Significant Difference (LSD) at 5% probability (Gomez and Gomez, 1984).

Results and Discussion

Soil physical properties

Soil physical properties showed identical changes over control treatment (Table 3) after incubation of soil samples by organic and inorganic amendments. The significantly higher percentage of WHC was recorded in treatment T_{12} (57.9%) which was at par with treatment T_{10} (50.6%). The result showed that gypsum addition was effective in reducing crust formation on sodic soils. A Combined application of organic and inorganic amendments played a significant ($P < 0.05$) role in improving WHC, similar results were recorded by Shaaban *et al.,* (2013). Soil porosity significantly increased in different treatments. The treatment T_{12} (57.6%) was at par with treatment T_{11} (52.2%). The combine application of spent wash and cluster bean straw changes the pore space due to release of enzyme and microbial activities which favours the synthesis of various organic compounds in soil and results in creation of micro and meso-pores (Kalaiselvi and Mahimairaja, 2010).

All treatments recorded a significant decreasing trend of BD (Table 3) over control (1.51 g cc^{-1}). Treatment T_{12} (1.16 g cc^{-1}) showed lowest BD and was at par with T_{10} (1.20 g cc^{-1}) and T_8 (1.21 g cc^{-1}). The organic matter decreases the bulk density of soil (Pravin *et al.,* 2013). Gypsum treated along with organic amendment showed overall best improvement in BD, these results were in confirmation with Jenkins and Jenkins (2014). Different treatment affected aggregation, bulk density and porosity and it was very well reflected on hydraulic conductivity. The hydraulic conductivity was much higher in T_{12} (1.02 cm hr^{-1}) which was at par with T_{10} (0.82 cm hr^{-1}).The level of hydraulic conductivity (Table 3) showed a significant increase in different treatments as compared to control ($T_{13,}$ 0.07 cm hr^{-1}). Addition of gypsum and amalgamated organics with or without crop straw, decays high amount of OM due to inter combination synergic effect of gypsum and DSW gave significantly higher hydraulic conductivity level respectively (Lado *et al.,* 2003).

The highest soil aggregate (> 125µ) percentage was recorded under treatment T_5 (40.7%) which was at par with T_{12} (40.2%) and lowest percentage was recorded in control treatment (25.6%). Application of DSW increased total and water stable soil aggregate percentage with size >125µ. Application of DSW was found very effective may be due to higher dose of distillery spent wash @5 Lac L ha^{-1}; having good organic content (>1.0%), binding chemical agents and used for reclamation of sodic soil (Gupta and Khan, 2015).

Soil chemical properties and available nutrient status

Individual as well as combined effects of amendments in increasing initial EC, which was highly significant ($P < 0.05$) in T_{12} (0.54) and was at par with T_{10} (0.47). An upward trend of EC was found in soil due to influence of spent wash; better result were observed with combine application along with inorganic amendment which increased soil EC (0.22-0.29 dS m^{-1}) remarkably (Das *et al.*, 2010). Soil pH was lowest in treatment T_{12} (7.6) which was at par with treatment T_{10} (7.7) and was highest in control (8.3). The study revealed that addition of gypsum and organic amendments (Straw, spent wash) affected soil as a result of decreased pH. Chemically, spent wash is highly acidic (pH, 3.7-4.1) and self-moving leaching was more effective in changing EC and pH. Gypsum application in combination with organic amendments improved the soil chemical properties by reducing the EC, SAR and pH, than the applying gypsum alone. Similar trends were reported by Khattak *et al.*, 2007 and Prapagar *et al.*, (2012).

Table.1 Physico-chemical characteristic of spent wash

Spent Wash				Biochar	
Parameters	Value	Parameters		Parameters	Value
Color	Brown	Chloride	250 mg L^{-1}	Ash Content	13%
Odor	Alcoholic	Calcium	261 mg L^{-1}	pH_{CaCl2}	6.9
pH	3.5 - 4.2	Magnesium	68 mg L^{-1}	CEC	176 $mmol_+$ kg^{-1}
DO	1.5 mg L^{-1}	Sulphate	419 mg L^{-1}	Specific surface area	324 m2 g^{-1}
BOD	5970 mg L^{-1}	Iron	2.8 mg L^{-1}	Particle fraction	5 × 6 × 0.5 mm
COD	3682 mg L^{-1}	Lead	0.065 mg L^{-1}	K	16.1 g kg^{-1}
Oil and Grease	12 mg L^{-1}	Zinc	0.26 mg L^{-1}	Ca	28 g kg^{-1}
Temperature	80^{o}C	Copper	0.135 mg L^{-1}	Fe	2.8 g kg^{-1}
Electrical Conductivity	2.23dS m^{-1}	Nitrogen	927 mg L^{-1}	C_{total}	64% (w $w^{-1)}$
Total dissolved Solid	1480 mg L^{-1}	Potassium	113 mg L^{-1}	N	1.1% (w w^{-1})
Suspended Solid	790 mg L^{-1}	Phosphate	45.6 mg L^{-1}		

Table.2 Experimental Treatments

Tr. No.	Treatment
T_1	Gypsum @ 1 t ha^{-1}
T_2	Gypsum @ 2 t ha^{-1}
T_3	Straw of clusterbean (straw) @ 20 t ha^{-1}
T_4	Biochar @ 10 t ha^{-1}
T_5	Distillery Spent wash (DSW) @ 5 Lac L ha^{-1}
T_6	Gypsum + Straw of cluster bean ($T_1 + T_3$)
T_7	Straw of cluster bean+ Biochar ($T_3 + T_4$)
T_8	Gypsum+ Spent wash ($T_1 + T_5$)
T_9	Gypsum + Biochar($T_1 + T_4$)
T_{10}	Gypsum + Spent wash ($T_2 + T_5$)
T_{11}	Straw of cluster bean + Spent wash (T_3+ T_5)
T_{12}	Gypsum + Straw of cluster bean + Spent wash (T_1 + T_3 +T_5)
T_{13}	Control

Table.3 Effect of organic and inorganic amendments on soil physical properties

SN	Treatment	Water holding capacity %	Porosity %	BD (g/cc)	Hydrolic conductivity (cm/hr)	Soil Aggrigates >125 µ
T_1	Gypsum @ 1 t ha^{-1}	34.3	46.8	1.39	0.15	34.8
T_2	Gypsum @ 2 t ha^{-1}	37.4	47.4	1.41	0.27	31.8
T_3	Straw of cluster bean @ 20 t ha^{-1}	35.8	44.1	1.42	0.24	26.8
T_4	Biochar @ 10 t ha^{-1}	33.2	46.4	1.48	0.18	34.6
T_5	Spent wash @ 5 Lac L ha^{-1}	33.8	52.1	1.27	0.35	40.7
T_6	Gypsum + Straw of cluster bean (T_1 + T_3)	36.6	49.1	1.35	0.24	34.1
T_7	Straw of cluster bean + Biochar (T_3 + T_4)	37.8	50.8	1.30	0.11	31.0
T_8	Gypsum + Spent wash (T_1 + T_5)	34.9	50.9	1.21	0.38	39.3
T_9	Gypsum + Biochar (T_1 + T_4)	40.8	48.8	1.35	0.28	31.4
T_{10}	Gypsum + Spent wash (T_2 + T_5)	50.6	53.3	1.20	0.82	35.4
T_{11}	Straw of cluster bean + Spentwash (T_3+T_5)	43.3	52.2	1.26	0.33	31.4
T_{12}	Gypsum + Straw of cluster bean + Spent wash (T_1 + T_3 + T_5)	57.9	57.6	1.16	1.02	40.2
T_{13}	Control	21.8	40.1	1.51	0.07	25.6
	S.E. ±	0.70	0.03	1.38	0.03	0.70
	C.D. (5%)	2.03	0.10	4.02	0.07	2.05

S.E.- standard error C.D.- critical difference; significantly different ($P < 0.05$)

Table.4 Effect of organic and inorganic amendments on soil chemical properties and fertility status

S N	Treatment	pH	EC (dS/m)	Available nutrients (kg/ha) N	P	K	OC (mg/kg)
T_1	Gypsum @ 1 t ha^{-1}	8.0	0.26	205	12	241	64
T_2	Gypsum @ 2 t ha^{-1}	8.1	0.26	296	13	369	80
T_3	Straw of cluster bean @ 20 t ha^{-1}	7.9	0.28	304	9	499	88
T_4	Biochar @ 10 t ha^{-1}	8.1	0.23	273	11	459	62
T_5	Spent wash @ 5 Lac L ha^{-1}	7.9	0.42	543	8	425	73
T_6	Gypsum + Straw of cluster bean (T_1 + T_3)	8.0	0.34	365	7	609	90
T_7	Straw of cluster bean + Biochar (T_3 + T_4)	7.9	0.37	299	5	890	90
T_8	Gypsum + Spent wash (T_1 + T_5)	7.7	0.46	684	13	985	136
T_9	Gypsum + Biochar (T_1 + T_4)	8.2	0.31	202	10	391	95
T_{10}	Gypsum + Spent wash (T_2 + T_5)	7.7	0.47	970	16	1066	154
T_{11}	Straw of cluster bean + Spentwash (T_3+T_5)	7.8	0.33	512	6	835	128
T_{12}	Gypsum + Straw of cluster bean + Spent wash (T_1 + T_3 + T_5)	7.6	0.54	1046	17	1229	155
T_{13}	Control	8.3	0.12	182	4	216	53
	S.E. ±	0.08	0.04	22.78	0.65	17.98	3.58
	C.D. (5%)	0.24	0.12	66.24	1.91	52.28	10.39

S.E.- standard error C.D.- critical difference; significantly different ($P < 0.05$)

Table.5 Assessment of percent improvement in soil properties and Soil Health Evaluation Index (SHEI) over control treatment

SN	Treatments	Water holding cpacity	Porosity	BD	Hydraulic conductivity	Soil aggregates (> 125µ)	pH	EC	OC	SHEI Index
		----------Percentage (%) improvement ----------								
T_1	Gypsum @ 1 t ha^{-1}	57	16	07	114	35	3	110	19	0.45
T_2	Gypsum @ 2 t ha^{-1}	71	18	06	285	24	2	100	49	0.69
T_3	Straw of cluster bean @ 20 t ha^{-1}	64	10	05	242	04	4	127	63	0.65
T_4	Biochar @ 10 t ha^{-1}	52	15	01	157	34	2	085	15	0.45
T_5	Spent wash @ 5 Lac L ha^{-1}	55	29	05	400	58	4	239	37	1.05
T_6	Gypsum + Straw of cluster bean (T_1 + T_3)	67	22	10	242	32	3	178	69	0.78
T_7	Straw of cluster bean + Biochar (T_3 + T_4)	73	26	13	057	21	4	202	69	0.58
T_8	Gypsum + Spent wash (T_1 + T_5)	60	27	19	442	53	7	276	154	1.30
T_9	Gypsum + Biochar (T_1 + T_4)	87	21	10	300	22	1.5	149	76	0.83
T_{10}	Gypsum + Spent wash (T_2 + T_5)	132	33	20	1057	38	7	278	186	2.13
T_{11}	Straw of cluster bean + Spentwash (T_3+T_5)	98	30	16	371	22	6	165	139	1.12
T_{12}	Gypsum + Straw of cluster bean + Spent wash (T_1 + T_3 + T_5)	165	43	23	1342	56	8	334	189	2.70

Increase in fertility are not accommodated in table but are included for computation of SHEI

Markedly increased available N, P, K status were recorded in DSW alone or in combination with straw and gypsum treatments, this might be due to the presence of considerable amount of N (927 mg L^{-1}), P (45.60 mg L^{-1}) and K (113 mg L^{-1}) in spent wash itself. Available N content was significantly increased under different treatments as compared to control and was found in the range of 205-1046 kg ha^{-1}. In term of depletion and build-up highest available N was recorded under treatment T_{12} (1046 kg ha^{-1}) which was at par with treatment T_{10} (970 kg ha^{-1}) and showed very high build-up over control (182 kg ha^{-1}).

Similarly, the increased microbial activity due to added organic matter through cluster-been straw which had increased the availability of nitrogen. The spent wash not only adds nitrogen to soil, but also promotes the mineralization and/or solubilisation of nitrogen in soil (Kalaiselvi and Mahimairaja, 2010 and Shenbagavalli *et al.,* 2011).

The significantly (*P*< *0.05*) higher available P was recorded in treatment T_{12} (17 kg ha^{-1}) which was at par with treatment T_{10} (16 kg ha^{-1}), lowest available P was recorded under the treatment T_{13} (4 kg ha^{-1}). The combine application of spent wash along with organics and gypsum markedly increased the available P status in the soil. The increase in available P may be assigned due to decomposition of distillery effluent helped to solubilise the immobile native soil organic P compounds and higher phosphatase activity in soil (Rajukannu *et al.,* 1996).

Available K in soil was significantly increased with application of higher amount, spent wash put together with gypsum and decomposable straw. The highest Available K was observed in treatment T_{12} (1229 kg ha^{-1}) which was at par with treatment T_{10} (1066 kg ha^{-1}). The lowest available K was recorded in treatment under control (216 kg ha^{-1}). The organic carbon significantly increased by different organic and inorganic amendments added to various treatments alone or in combinations respectively over control treatment (Kavitha et. al. 2014). The maximum organic carbon concentration was recorded under combined application of gypsum + cluster been straw + DSW treatment (T_{12}; 155 mg kg^{-1}) which was at par with treatment T_{10} (153 mg kg^{-1}) and lowest concentration of OC was recorded under control (53 mg kg^{-1}) treatment (table 4). As the level of spent wash application increased, organic carbon content was increased. This could be attributed to the fact that spent wash had high organic load thus triggering microbial activity. Similar results were reported by Meena *et al.,* (2013).

Soil health elevation and soil health elevation index (SHEI)

The improvement in soil health was noticed after different amendments application to the soil. The parameters involved in soil health status and their elevation remarkably improved under all treatment pots as compared to control treatment. Various amendments noticeably increased percentage of WHC, % porosity, hydraulic conductivity, soil aggregate, EC and OC of soil under different treatments; whereas negative trends were recorded in pH and BD of soil (Table 5).

The highest increase in percentage of different soil properties was recorded under T_{12} viz. WHC by 165%, porosity by 43%, hydraulic conductivity (1342%), EC (334%) and OC by 189% where as soil aggregate under T_5 by 56%; and negative highest changes were recorded for BD by 23% and pH by 8% under T_{12}.

In present study SHEI was considered as very good index for predicting soil health improvement due to application of various amendments. The positive value can be categorised as any changes < 1.0 as marginal, 1.0- 2.0 as good, and >2.0 considered as excellent elevation/ improvement. After considering all the parameters including fertility elevation higher mean value of SHEI was recorded under T_{12} (2.70) fallowed by T_{10} (2.13) which showed excellent improvement in soil health; T_8 (1.30), T_{11} (1.12) and T_5 (1.05) showed good elevation; whereas remaining treatments recorded marginal elevation in soil health. On the basis of computed SHEI index higher value 2.70 was recorded under treatment receiving gypsum + straw + DSW which was found excellent one for the assessment of overall improvement in soil health under various treatments as per study limits. The SHEI computation with this formula gave very authentic information regarding up gradation in soil heath due to various treatments application and their effectiveness. This formula is adjustable to many numbers of soil properties for considerations as much as possible. Here the value for grading of soil health elevation, it was considered that < 1.0 as no elevation, 1.0- 2.0 as considerable elevation and >2.0 as excellent elevation and there is flexibility to lower down this limit in case of soils from most degraded to partially degraded or even more to a normal soil.

In conclusions, the experimental finding revealed that combined application of gypsum, straw of cluster bean and DSW with their various doses found to be superior in respect of soil physical and chemical properties. Treatment T_{12} showed identical changes with respect to WHC (57.9%), BD (1.16), porosity (57.6%), hydraulic conductivity (1.02cm hr^{-1}) EC (0.54 dSm^{-1}), pH (7.6); as well as soil fertility status (N: 1046, P: 17 and K: 1229 kg ha^{-1}) and OC (155 mg kg^{-1}) also. Whereas only total soil aggregate (>125µ) found higher in DSW (T_5) alone treatment (40.7) compared with other treatment. SHEI found excellent result with respect of elevation in soil health improvement and it is very dynamic for computation as there is no limit for number of parameters or present soil health condition. Highest SHEI (2.70) recorded in Treatment T_{12}. From the present study it may be concluded that application of spent wash which was highly acidic and source of plant nutrients. Use of organic waste with inorganic amendments like gypsum was found very beneficial for correcting all soil constraints and improving soil health. The computation of SHEI is very dynamic in nature and can be used for health of any kind of soil and number of properties.

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References

Angers D.A. and Mehuys G.R., 1993. Aggregate stability to water. In: Carter MR (Ed)

Chapter 61. *Soil Sampling and Methods of Analysis*. 651-657. CRC Press, Boca Raton, Florida.

Anonymous 2013. Annual Report of Niche Area of Excellence on Management of Soil Health in Degraded Chambal Ravine, submitted to Indian Council of Agricultural Research, New Delhi, India

Black, C.A. 1965. *Methods of soil Analysis Part I and II*. American Society of Agronomy, Inc. Publishers, Madison, Wisconsin, USA.

Blake, G.R., and K.H., Hartge 1986. Bulk density. In: A. klute ed. methods of soil analysis part I: physical and mineralogical methods.2nd *edi. Am. Soc. Agron., Madison, WI*: 363-375.

Carter, M.R., Gregorich, E.G., Anderson, D.W., Doran, J.W., Janzen, H.H., and Pierce, F.J., 1997. Concepts of soil quality and their significance. In: Gregorich, E.G., Carter, M.R. (Eds.), *Developments in Soil Science.* Elsevier, pp. 1–19

Das M., Charaborty H., Singandhupe R.B., Muduli S.D., and Kumar A., 2010. Utilization of distillery wastewater for improving production in underproductive paddy grown area in India. *Journal of scientific and industrial research.* 69, 560-563.

Doran, J. W. and Jones, A. J. (eds) 1996 *Methods for assessing soil quality*, vol. 49. *SSSA* special publication. Madison, WI: ASA.

Doran, J. W. and T. B. Parkin. 1994. Defining and assessing soil quality. Pp 3–22 in J. W. Doran, D. C. Coleman, D. F. Bezdicek, and B. A. Stewart, eds. Defining soil quality for a sustainable environment. Soil Science Pub. 35. Madison, WI: *American Society of Agronomy.*

Gomez, K.A. and A.A. Gomez, 1984. *Statistical procedures for agricultural research* (2 ed.). John wiley and sons, New York, 680p.

Khattak S.G., Haq I.U, Malik A., Khattak M. J., and Naveedullah, 2007. Effect of various levels of gypsum application on the reclamation of salt affected soil grown under rice followed by wheat crop. *Sarhad J. Agric.* 23(3)*: 675-680.*

Gupta R., and Khan M.Z. 2015. Effect of Distillery Effluent (spent wash) application on aggregate size distribution and stability in sodic soils. *Sugar Tech.* 17: 367. Doi: 10.1007/s12355-014-0326-1 December 2015. 17, 367–378.

Hendrix, P. F., D. C. Coleman, and D. A. Crossley, Jr. 1992. Using knowledge of soil nutrient cycling processes to design sustainable agriculture. *J. Sust. Agri.* 2, 63–81.

Hoitink, H. A. J., D. Y. Han, A. G. Stone, M. S. Krause, W. Zhang, and W. A. Dick. 1997. Natural suppression. American Nursery man. October 1, 1997:90–97.

Jackson, M. L., 1967. *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Jenkins T. A. and Jenkins V. 2014 Effects of gypsum on soil quality: preliminary results. Centre for Sustainable Agricultural Technologies Ltd P.O. Box 29683, Christchurch 8540, New Zealand

Kalaiselvi P. and Mahimairaja S. 2010. Effect of spentwash application on nitrogen dynamics in soil. *International J. Env. Sci. Dev.,* 1 (2) ISSN: 2010-0264.

Kavitha H., Bhaskar S. and Kavitha M.Y. 2014. Effect of distillery spent wash on growth and yield parameter of sunflower (*Helianthus annuus* L.) soil chemical properties and economics in dryland agroecosystem. *Adv. Res. J. Crop Improvement,* 5: 1-6.

Lado M., Paz A., Ben and Hur M. 2003. Organic Matter and Aggregate-Size Interactions in Saturated Hydraulic Conductivity. Doi: 10.2136 / *Soil Sci. Soc. Amer J.*, 2004.2340. 68 (1): 234 242.

Larson, W.E.& Pierce, F.J., 1991. Conservation and enhancement of soil quality Evaluation for sustainable land management in the developing world. In: IBSRAM Proceedings, No. 12 Vol. 2, Technical Papers, Bangkok, Thailand, pp. 175–203.

Masek, O. 2009. Biochar production technologies, http://www.geos.ed.ac.uk/sccs/ biochar/ documents/ BiocharLaunch-OMasek.pdf.

Magdoff, F., and H. Van Es. 2000. Building soils for better crops, 2nd ed. Burlington, VT: Sustainable Agriculture Network.

Magdoff, F., L. Lanyon, and B. Liebhardt. 1997. Nutrient cycling, transformations, and flows: Implications for a more sustainable agriculture. *Adv Agr*. 60, 1–73.

Manna M. C. Rao A. Subba and Manadal A. 2013. Maintenance of soil biological health under different crop production systems. *Ind. J. Soil Cons.* 41, (2): 127-135.

Meena, M.C. Patal K.P. and Raman. V.P. 2013. Effect of FYM and sewage sludge application on yield and quality of pearl millet- mustard cropping system and soil fertility in typic haplustept. *J. Indian Soc. Soil Sci.* 61 (1), 55 -58.

Muhr, G.R., Datta, N.P., Sankarasubramaney, H., Dever, F., Laley, V.K. and Donahue, R.L., 1963. Critical test value for available N, P and K in different soils. *Soil Testing in India*, 2nd edn. U.S. Agency for International Development, New Delhi, 120.

Olsen S.R., Cole C.V., Watnbe F.S. and Dean L.A. 1954. Estimation of available phosphorus in soil extraction with sodium bicarbonate. *USDA Circ. 939.*

Pravin, R., Chaudhari., Dodha, V., Ahire, Vidya, Ahire, D., Chkravarty, M. and Saroj Maity 2013 Soil Bulk Density as related to Soil Texture, Organic Matter Content and available total Nutrients of Coimbatore Soil. *Int. J. Scientific Res. Pub.* 3, 1-8.

Parr, J.F., Papendick, R.I., Hornick, S.B. and Meyer, R.E., 1992. Soil quality: attributes and relationship to alternative and sustainable agriculture. *Ame. J. Alter. Agri.* 7, 5–11.

Piper, C. S., 1966. *Soil and Plant Analysis*. Hans Publishers, Bombay.

Prapagar, K., Indraratne S.P. and Premanandharajah P. 2012. Effect of soil amendments on reclamation of saline-sodic soil. *Tropical Agri. Res.* 23 (2), 168 –176.

Rajukkannu, K., Manickam, T.S., Chandrasekaram and Gladis, R. 1996. Proceedings of National symposium on use of distillery and sugar industry wastes in agriculture. 28-29 Oct 1996, AC and RI. Trichy. 30 -39.

Shaaban M., Abid M. and Abou-Shanab R.A.I. 2013. Amelioration of salt affected soils in rice paddy system by application of organic and inorganic amendments. *Plant Soil Environ.* 59 (5): 227–23.

Shenbagavalli S., Mahimairaja S. and Kalaiselvi P. 2011. Impact of biomethanated distillery spent wash application on soil water quality: field appraisal *Int. J. Envr. Sci.* 1 (7).Subbaiah, B.V. and Asija, G.L., 1956. A rapid procedure for the estimation of available nitrogen in soil. *Current Science.* 25: 259.

Somasundaram J; Lakaria B L; Saha R; Sinha N K; Jha P; Chaudhary R S; SinghR K; Mandal D; HatiK M; Ramesh K; Coumar M Vassanda; Biswas A K; Dey P.; Reddy K Sammi and Rao A. Subba 2014. Management of Stressed Soils of Dryland Agriculture in Semi-Arid Tropics-A review. *Ind. J. Soil Cons.*, 42(2): 178-187.

Van-Camp, L., Bujarrabal, B., Gentile, A. R., Jones, R. J. A., Montanarella, L., Olazabal, C. and Selvaradjou, S.-K.

2004. Reports of the technical working groups established under the thematic strategy for soil protection, vol. 5 Monitoring. EUR 21319 EN/5, pp. 653–718. Luxembourg, Europe: European Communities

Walkley, A. and Black, C.S. 1934. An examination of Degtjareff methods for determination of soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci.*, 37, 29- 38.

Warkentin, B.P., and Fletcher, H.R., 1977. Soil quality for intensive agriculture Proceedings of the international seminar on soil environment and fertility management in intensive agriculture. *Soc. Sci. Soil Manure*. Japan 594–598.