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Research Article

EFFECT OF SUBSURFACE DRAINAGE SYSTEM AND AMENDMENTS ON SOIL QUALITY PARAMETERS UNDER WATERLOGGED SALINE ALKALI SOIL

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Abstract- The continuous irrigation of treated wastewater over many years, without proper management leads to accumulation of salts in soil profile (salinization), reduction in hydraulic conductivity of soil, waterlogging and it leads yield reduction. A subsurface drainage system field experiment (Sunflower) was conducted in split plot design to study the effect of subsurface drainage system and influence of amendments on saline alkali soil reclamation. The experiment consists of 2 main plots (drained field and undrained field) and seven subplots with different amendments. Among the drainage system and amendments, the amendments application in drained field improved the soil quality parameters by reducing soil pH, EC and ESP over undrained field. The application of FYM along with gypsum requirement and recommended dose of fertilizer reduced soil pH, EC and ESP. The application of FYM reduced the ESP 46.42 per cent in drained field over undrained control. The drainage system reduced the soil salinity and improved the soil quality parameters.

Keywords- Subsurface drainage system, Amendments, Saline alkali soil, Soil quality, ESP

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Introduction

The increasing water requirement to meet agriculture, domestic and industrial demands from other sector indicate the need for regeneration of wastewater and use of treated industrial wastewater for irrigation in dryland area. It is a alternative, attractive and cost effective approach to discharge the effluent into natural waterways [1], [2] Economic benefits of the pulp and paper industry has made this sector as one of the most important industrial sections in the world. In India there are 759 pulp and paper mills with an installed capacity of 12.7 Mtpa, producing around 10.90 Mtpa paper, paper board and newsprint [3]. The Indian pulp and paper industry, consuming 100-250 m^3 of water per ton of paper production, this amount reappears as wastewater [4] ,[5] and after treatment, this water can be safely used for crop production with addition of suitable organic amendments [6], [7]. As a result of continuous addition of salts through effluent irrigation, associated with insufficient leaching of salts in soil profile leads to development of saline alkali condition, waterlogging and finally yield reduction in crops [8]. The adverse effects such as high soil ESP, reduced permeability and ion toxicity would be alleviated by application of NPK along with inorganic and organic amendments [9] ,[10].

Adoption of subsurface drainage system is probably one of the best way to sustain natural resources like soil and water in severely waterlogged saline soil [11]. There is a great demand for the research and developmental efforts to reclaim the salt affected and waterlogged soil by providing drainage and bring them back to productive soil.

Materials and Methods

The experimental site (11°02'189 North latitude and 77°99'736 East longitude) having waterlogging and saline alkaline nature had been selected at Pandipalayam village, Karur District, Tamil Nadu. The subsurface drainage system installed in an area of 0.5 ha by adopting lateral spacing of 15 m between laterals. The lateral (80 mm diameter, perforated corrugated flexible PVC pipes) placed in a depth of 1.1 to 0.9 m from the surface and main drainage (blind PVC) pipe of 110 mm placed in a depth of 1.2 m from the surface. The field was prepared with beds and channels and the experiment conducted during July - December 2014, in split plot design and replicated thrice with seven amendments. The sunflower (variety CO SFV 5) seeds were sown by adopting spacing of 40 x 30 cm in ridges and furrows on September, 2014 and harvested on December, 2014. The TNAU recommended package of practices were followed for the entire crop growth period. The treated paper mill effluent was used as a source of irrigation.

Treatment Details

Main Plot	: M_1- Subsurface drainage system field
	: M_2- undrained field
Sub plot	
S_1	: Control
S_2	: 100 % GR
S_3	: 100 % GR + FYM @ 12.5 t ha^{-1}
S_4	: 100 % GR + MLSS compost @ 5.0 t ha^{-1}
S_5	: 100 % GR + Vermicompost @ 5.0 t ha^{-1}
S_6	: 100 % GR + Pressmud @ 5.0 t ha^{-1}
S_7	: 100 % GR + Biochar @ 5.0 t ha^{-1}

Common application: Recommended Dose of NPK: 60:30:30 kg ha^{-1}; GR - Gypsum Requirement
(FYM - Farm Yard Manure; MLSS compost – Mixed liquid suspended solids compost)

Soil sample collection and analysis

The soil samples were collected at different stages *viz.,* vegetative (30 DAS), heading (60 DAS) and at harvest stage. The collected soil samples were processed and used for analyzing various physico-chemical properties by following standard methods [Table-1].

Table-1 *Standard methods followed for the analysis of soil samples*

Parameter	Method	Unit	Reference
Soil reaction(pH)	Potentiometry soil water suspension of 1:2.5 ratio	-	[12]
Electrical Conductivity (EC)	Conductimetry soil water suspension of 1:2.5 ratio	dS m^{-1}	[12]
Exchangeable Na and K	Flame photometer	cmol (p^{+}) kg^{-1}	[12]
Exchangeable Ca and Mg	Versanate titration method	cmol (p^{+}) kg^{-1}	[12]
Exchangeable Sodium Percentage (ESP)	$\frac{Na^{+}}{Na^{+}+Ca^{++}+Mg^{++}+k^{+}} \times 100$	-	[13]

Results and Discussion

In general subsurface drainage system and amendments significantly influenced most of the soil quality parameters and reduced the levels of pH, EC and ESP than initial soil under paper mill effluent irrigation.

Soil physiochemical properties

Soil reaction (pH)

The soil pH play an important role in availability of plant nutrients in saline alkali soil. The drainage system and organic amendments significantly reduced the soil pH at harvest stage of sunflower [Fig-1]. Significant differences in soil pH was noticed between drained and undrained field, it showed a decreasing trend in drained field and slightly increasing trend in undrained field. The decrease in soil pH was due to the removal of sodium and bicarbonates ions along with leaching water through drainage in drained field [14,15]. The decomposition of added organic amendments will release various organic acids, that provides H^{+} ions to soil and finally decrease the soil pH. Similar findings were reported by [9,16] the application of organic amendments along with 50 per cent gypsum requirement reduced the soil pH of post-harvest sugarcane soil under poor quality irrigation.

Among the amendments, application of FYM @ 12.5 t ha^{-1} + 100 per cent GR, recorded maximum reduction in soil pH followed by pressmud application @ 5 t ha^{-1} + 100 per cent GR. Application of FYM decreased soil pH by decreasing the precipitation of Ca^{2+} and CO_3^{2-} and increased the removal of Na^{+} in drainage water [17]. Similarly the reduction in pH, while applying FYM and pressmud were also reported by [18,19]. The increasing trend of soil pH in undrained field might be due to continuous addition of chlorides, sodium and bicarbonate ions through effluent water. [20] reported that, the pH of the paper mill effluent irrigated soil turns from alkaline to more alkaline, when irrigation with 100 per cent paper mill effluent.

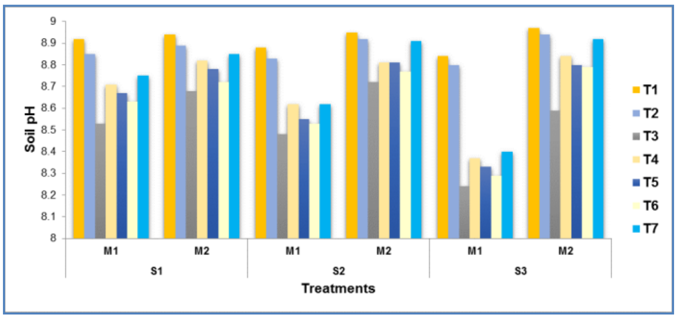

Fig-1 Effect of subsurface drainage system and amendments on soil pH at different growth stages of sunflower

Electrical Conductivity (EC)

Provision of drainage system and application of organic amendments significantly influenced the soil EC [Fig-2]. Significantly, lower EC was recorded in drained field towards crop advancement whereas undrained field showed an increasing trend. The subsurface drainage system shows decrease in soil EC due to leaching of soluble salts (sodium and chloride) from soil profile, which otherwise would have been concentrated in soil solution and accumulated in soil [14,15]. The subsurface drainage system prevents the rise of groundwater table, there by salts accumulation in the plough layer of soil [21].

Application of gypsum and organic amendments significantly decreased the soil EC by leaching down the concentration of soluble salts through drainage effluent. Organic amendments and gypsum are good contributor to the cause, gypsum provides Ca to replace sorbed Na and amendments boost the process by providing organic, inorganic acids and CO_2 to dissolve precipitated $CaCO_3$ to liberate more calcium for replacement of Na and subsequent leaching by drainage effluent water. Which is in line with findings of [9,16,22] they reported that the application of organic amendments and gypsum reduce the electrical conductivity of soil by replacing sodium by calcium in the exchangeable complex. Furthermore, the continuous availability of moisture in rhizosphere regions might also have prevented the capillary rise of salt from the subsurface layer of soil [9,16] due to application of organic amendments.

At harvest stage among the amendments the lowest EC of 4.03 dS m^{-1} recorded in the treatment which received FYM @ 12.5 t ha^{-1} + 100 per cent GR, which was also on par with T_4, T_5 and T_6. The highest EC of 5.43 dS m^{-1} recorded in undrained field at harvest stage, which received RDF alone. The absence of drainage would concentrate soluble salts and increased the soil conductivity in undrained field and this was in line with finding of [14,15] they reported field without drainage system concentrate salts in soil and increased soil EC. [6,7] reported that paper mill effluent contain considerable amount of salts which develop alkalinity in soil.

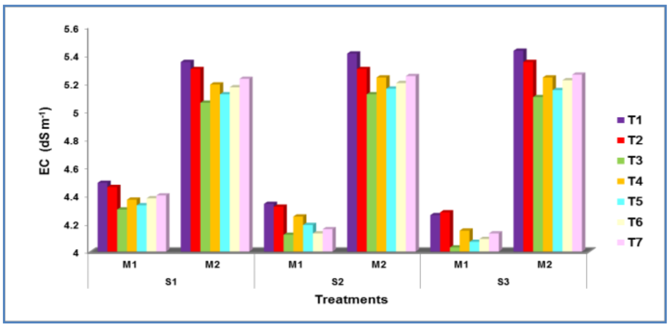

Fig-2 Effect of subsurface drainage system and amendments on soil EC (dS m^{-1}) at different growth stages of sunflower

Exchangeable cations

The subsurface drainage system and amendments significantly influenced the soil exchangeable cation like calcium, magnesium and potassium, it showed increasing trend towards crop advancement [Fig-3-6]. Significantly higher exchangeable calcium content was recorded in drained field, whereas magnesium and potassium showed reverse trend and undrained field recorded slightly higher content.

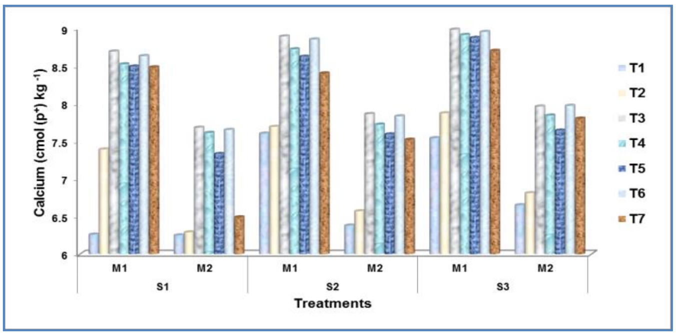

Fig-3 Effect of subsurface drainage system and amendments on soil exchangeable calcium (cmol (p+) kg-1) at different stages of sunflower growth

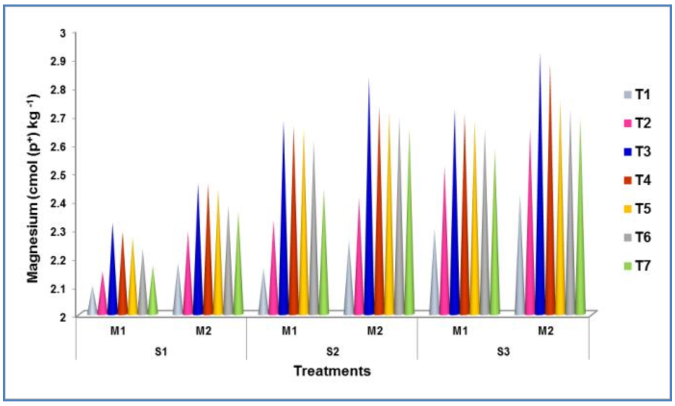

Fig-4 Effect of subsurface drainage system and amendments on soil exchangeable magnesium (cmol (p+) kg-1) at different stages of sunflower growth

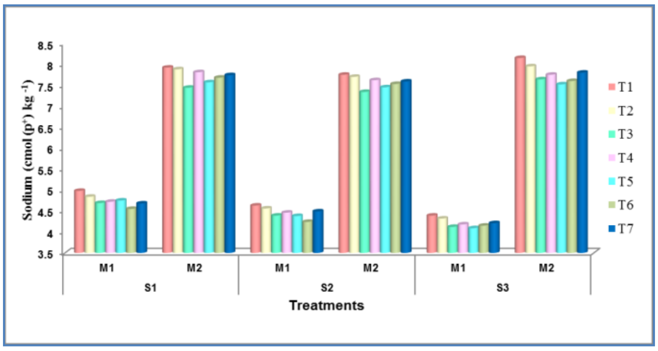

Fig-5 Effect of subsurface drainage system and amendments on soil exchangeable sodium (cmol (p+) kg -1) at different stages of sunflower growth

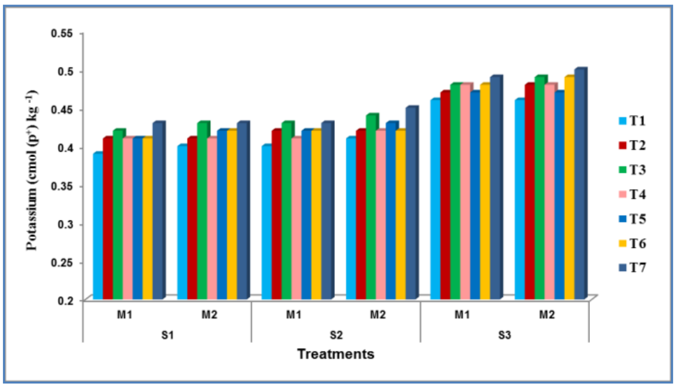

Fig-6 Effect of subsurface drainage system and amendments on soil exchangeable potassium (cmol (p+) kg -1) at different stages of sunflower growth

M1 - subsurface drainage system; M2 - Undrained field

T1 - Control; T2 -100 % GR; T3 - FYM @12.5 t ha-1 + 100 % GR; T4 - MLSS compost @ 5.0 t ha-1 + 100 % GR; T5 - Vermicompost @ 5.0 t ha-1 + 100 % GR; T6 - Pressmud @ 5.0 t ha-1 + 100 % GR; T7- Biochar @ 5.0 t ha-1 + 100 % GR. S1 - Vegetaitve stage; S2 - Heading stage; S3 - Harvest stage

The slow release nature of Ca from gypsum and organic amendments during the process of mineralization might be responsible for increased calcium content in drained field. This is in line with finding of [16], who reported poor solubility of gypsum may release calcium during entire crop growth of sugarcane. The replacement of Na from exchange complex by Ca and subsequent release of Ca from $CaCO_3$ by the action of organic and produced during decomposition of organic matter might also responsible for this increased calcium content in drained field [22]. The treated paper mill effluent had considerable amount of calcium which contributed to increased calcium content of soil under paper mill effluent irrigation. At harvest stage treatment received FYM @ 12.5 ha^{-1} +100 per cent GR recorded highest exchangeable calcium content of 8.98 cmol (p$^+$) kg^{-1}, closely followed by application of pressmud @ 5.0 t ha^{-1} (8.95), ETP sludge @ 5.0 t ha^{-1} (8.91) and vermicompost application. The lowest calcium content of 6.65 cmol (p$^+$) kg^{-1} soil recorded in treatment received RDF alone under undrained field condition. The highest calcium content in FYM and pressmud received treatment might be due to higher calcium content of the amendments (0.90 and 1.50 per cent, respectively in FYM and pressmud) and application rate (FYM @ 12.5 t ha^{-1} and pressmud @ 5.0 t ha^{-1}). Similarly other organic manures also supplied considerable quantity of Ca, Mg and K, would replaced the Na from exchangeable complex.

The exchangeable sodium recorded decreasing trend in drained field, whereas in undrained field it showed an increasing trend. The replacement of Na from exchangeable site by Ca and subsequent leaching through drainage effluent decreased the sodium content in drained field, which was accelerated by addition of organic amendments. At harvest stage of sunflower, the treatment received FYM @12.5 t ha^{-1} and gypsum requirement recorded lowest exchangeable sodium content of 4.12 cmol (p$^+$) kg^{-1} of soil in drained field, which was on par with application of ETP sludge @ 5.0 t ha^{-1}, vermicompost @ 5.0 t ha^{-1} and pressmud @ 5.0 t ha^{-1}.

Exchangeable Sodium Percentage (ESP)

Provision of drainage system and application of amendments significantly reduced the soil ESP. The influence of reduction in soil ESP was more in drained field than undrained field [Fig-7]. The ESP of soil varied from 28.8 to 47.3, 26.3 to 46.1 and 25.3 to 46.1 per cent during vegetative, heading and at harvest stages, respectively. At harvest stage, the lowest ESP was registered in treatment received FYM @ 12.5 t ha^{-1} + 100 per cent GR, which is on par with T_4, T_5 and T_6 in drained field.

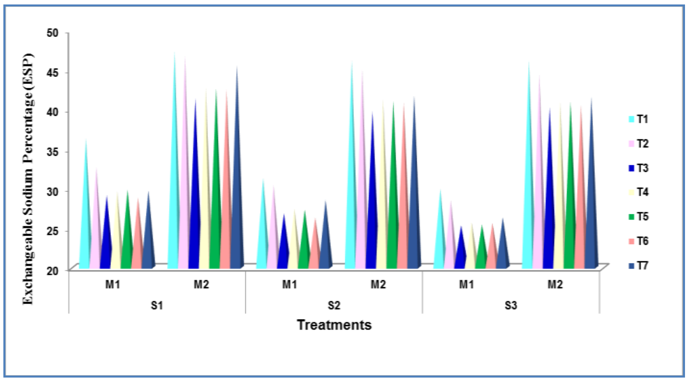

Fig-7 Effect of subsurface drainage system and amendments on soil exchangeable sodium percentage at different stages of sunflower growth

M_1 - subsurface drainage system; M_2 - Undrained field

T_1 - Control; T_2 -100 % GR; T_3 - FYM @12.5 t ha^{-1} + 100 % GR; T_4 - MLSS compost @ 5.0 t ha^{-1} + 100 % GR; T_5 - Vermicompost @ 5.0 t ha^{-1} + 100 % GR; T_6 - Pressmud @ 5.0 t ha^{-1} + 100 % GR; T_7- Biochar @ 5.0 t ha^{-1} + 100 % GR.

S_1 - Vegetaitve stage; S_2 - Heading stage; S_3 - Harvest stage

The amendments contain considerable amount of Ca, Mg and K, which was released in to soil during mineralization of organic matter. The released cations from organic amendments replacing the exchangeable Na from exchange complex and subsequently leached out through drainage effluent and this process is responsible to bring down the soil ESP towards crop harvest in drained field. This was supported by [14,15], the subsurface drainage leached down the soluble salts along with drainage effluent, which otherwise would have been concentrated in the soil solution and accumulated in soil and leading to increased soil ESP. [23] also reported that application of pressmud @ 5.0 t ha^{-1} + 100 per cent GR + recommended dose of NPK reduced soil ESP by 45 per cent.

Conclusion

The subsurface drainage system is a highly viable technology to sustain crop productivity where irrigation induced salinity and water logging limit crop productivity. Provision of subsurface drainage system and application of organic amendments had better influence on soil physiochemical properties and exchangeable cations in salt affected soil irrigated with treated paper mill effluent. It could be concluded that application of organic amendments, 100 per cent gypsum and recommended dose of nitrogen, phosphorus and potassium fertilizer are highly effective in reviving waterlogged, salt affected land into productive land by adopting subsurface drainage system and further studies are needed to confirm this result and visualize the impact on long run.

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Author Contributions:

The whole research work was carried out by Balusamy and co-author Dr. Udayasoorian contributed in terms of timely technical guidance and moral support to carry out the research.

Abbreviations used:

pH - Soil reaction; EC – Electrical Conductivity; ESP – Exchangeable Sodium Percentage; FYM – Farm Yard Manure; GR – Gypsum Requirement; MLSS compost – Mixed Liquor Suspended Solids

Ethical approval:

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of Interest: None declared

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