International Journal of Plant & Soil Science

Volume 35, Issue 20, Page 203-208, 2023; Article no.IJPSS.90059
ISSN: 2320-7035

Affected of Ameliorated Alkaline Water and Soil Amendments on Exchangeable Cation, Macro and Micronutrients in Sodic Soil under Drip Irrigation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i203799

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/90059

Original Research Article

Received: 10/06/2022
Accepted: 14/08/2022
Published: 19/09/2023

ABSTRACT

The Field experiment was carried out at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli using cotton (RCH- 20) as a test crop to examine the effect of ameliorated alkali water and soil amendments on soil properties, growth, and yield of hybrid cotton in sodic soil under drip irrigation. In this experiment, Drip irrigation with gypsum treatment water and drip irrigation with spent wash treatment water were used as main-plots treatments. Soil application of gypsum @ 50 % GR (5.2 t ha^{-1}) and one time soil application of distillery spent wash @ 5 lakh litter

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ha^{-1} were imposed as sub-plot treatments. The treatment without amendments both under main plot and sub plots were used as control. The experiment was carried out using a strip-plot design with four replications. The application of additives through irrigation water (or) soil considerably decreased the pH of post-harvest soil. The soil exchangeable Ca and Mg were found significant due to soil application of amendments only and value ranged from 8.51 to 9.35 and 5.03 to 5.20 Cmol (p+) kg^{-1} respectively. The soil available nutrients N, P and K were found significant, and value range from 167 to 311, 15.4 to 21.5, 158 to 928 kg ha^{-1} respectively. The application distillery spent wash (DSW) and gypsum slightly increased the micronutrient cations range which from 4.80 to 6.85 mg kg^{-1} of Fe, 8.60 to 10.43 mg kg^{-1} of Mn, 0.64 to 0.88 of mg kg^{-1} of Zn, 1.10 to 1.42 mg kg^{-1} of Cu. The results of the field experiment revealed that application of amended alkali water and amended soil significantly increased all the growth and yield parameters of cotton. An increase in seed cotton yield of 701 and 544 kg ha^{-1} was recorded due to the application of gypsum treated water and DSW treated water respectively over control. Similarly, an increase of 773 and 973 kg ha^{-1} of seed cotton yield was recorded due to soil application of gypsum and DSW respectively over control. While considering the interaction effect, soil application of DSW along with gypsum bed treated water found to be the best for getting higher seed cotton yield (3015 kg ha^{-1}) when compared to other treatment combination.

Keywords: Sodicity; gypsum; distillery spent wash; ameliorated alkali water; drip irrigation.

1. INTRODUCTION

"Concerns about food security and the lack of fresh productive land have pushed productivity improvement of degraded lands back onto research and development's agenda. Nearly 9.38 million hectares (ha) of land in India are covered by salt-affected soils, of which 5.50 million hectares (ha) are salty soils, 3.77 million hectares (ha) are alkali soils, and 3.5 lakh hectares (ha) are sodic soil. Sodicity is the main cause of the low productivity of crops grown on sodic soil. When the EC is less than 4.0 dsm-1 and the soil has a pH of more than 8.5, an ESP of 15.0 or more, and a preponderance of sodium CO_3 and HCO_3, the soil is referred to as --alkali. Excess sodium ions in soil make it sodic, which causes the dispersion of soil aggregates and inhibition of the soil microbial activity" [1,2]. "The crops growing in such soils are suffering with unavailability of plant essential nutrients, especially nitrogen (N), phosphorus (P), and potassium (K). The most common cations are calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^+), whereas the most abundant anions are chloride (Cl^-), sulphate (SO_4^{-2}), and bicarbonate (HCO_3). Sodic water is synonymous with 'soft' water. Sodicity can contribute to the deterioration of physical properties of the soil, which can indirectly affect plants resulting in surface crusting, reduced water infiltration, and reduced aeration causing anoxic or hypoxic conditions for roots [3,4]. Sodic soils can be reclaimed by different amendments which can be selected based on their availability and severity of problem. Because of its (i) moderate solubility, (ii) ability to replace sodium ion (Na+) on exchange sites with calcium ion (Ca^{2+}), and (iii) inexpensive cost and widespread availability, gypsum is a popular amendment for sodic soil restoration" [5,6,1,7,8]. "The shortage of organic manures such as FYM or compost, as well as the difficulty in obtaining and paying for gypsum, have limited the breadth of their use for reclamation. As a result, it is critical to find low-cost, locally available, highly efficient sources of reclamation. One such possibility is the use of raw wasted wash, an acidic byproduct of the distillery industry's effluent" [9,10]. Thus, the current experiment sought to investigate the effects of improved alkali water and soil amendments on soil characteristics, growth, and yield of hybrid cotton in sodic soil under drip irrigation.

2. MATERIALS AND METHODS

The experiment was conducted at the Anbil Dharma lingam agricultural college and research institute, Department of Soil Science and Agricultural Chemistry, Tiruchirappalli, Tamil Nadu (10 45 5.465 N,78.36 1.227 E). The soil was *Typic Ustropept with* clay texture. The field experiment was laid out in Strip plot design, four replication and three mail plots, three sub plots followed.

2.1 Main Plots (Irrigation Water Treatment)

M_1: Drip irrigation with gypsum treated water
M_2: Drip irrigation with spent wash treated water

$M_{3:}$ Drip irrigation with untreated alkali water

2.2 Sub Plots: Soil Treatment

$S_{1:}$ Soil application of gypsum @ 50% GR
$S_{2:}$ One time application of DSW @ 5 lakh litter ha^{-1}
$S_{3:}$ No treatments (control)

A few important yield related observation *viz.,* plant height, number of bolls per plant, seed cotton yield (kg ha^{-1}), soil related observation *viz.*, soil physico- chemical properties, exchangeable cations, available nutrients, micronutrients, microbial population and soil enzyme activities were recorded.

3. RESULTS AND DISCUSSION

3.1 Effect on Soil Exchangeable Cation

Only soil application of amendments was shown to be relevant for the soil exchangeable Ca and Mg, with values ranging from 8.51 to 9.35 and 5.03 to 5.20 cmol (p+) kg $^{-1}$, respectively (Table 1). "The natural free lime may have been solubilized by the raw spent wash's acidic pH of 3.8, releasing Ca and Mg in free ionic forms. This may have also contributed to the increased Ca and Mg on exchange sites with the displacement of exchangeable sodium. Similar findings about the application of raw waste wash increasing the Ca and Mg concentrations of soil were also reported" by Baskar et al. [9]. "Utilizing wasted wash in its concentrated form promoted a higher exchange of sodium for calcium, and subsequent leaching with high-quality water restored the sodium from the spent wash. Due to the makeup of the added organic amendments, the amount of exchangeable K increased with the addition of distillery waste wash. Gypsum and organic sources were added, which encouraged Na displacement and its subsequent removal during irrigation to lower soil layers, which resulted in a decrease in soil ESP with the addition of amendments (organic or inorganic), either alone or in combination" [5].

3.2 Effect on Available Nutrients

The soil available nutrients N, P and K were found significant, and value range from 167 to 311, 15.4 to 21.5, 158 to 928 kg ha^{-1} respectively (Table 2). An increase in available N content of 6 and 13 kg ha^{-1} was registered by (M_1) drip irrigation with gypsum treated water and drip irrigation with spent wash treated water (M_2) respectively over the control (M_3). The highest value (302 kg ha^{-1}) was recorded due to soil application of distillery spent wash (S_2). The lowest value (170 kg ha^{1}) was registered by the control (S_3). Increase in soil phosphorus availability by addition of various organic materials have been reported by several workers [10]. The out-turn of main-plot and sub plot treatments showed a significant increase in the available K content of the soil. The combined effect of irrigation treatments and soil amendments on available K content also found to be significant. The treatments M_2S_2 (drip irrigation with DSW treated water + soil application of DSW) and M_3S_3 (absolute control) recorded the highest (928 kg ha^{-1}) and lowest (158 kg ha^{-1}) available K content in post-harvest soil, respectively. Spent wash contains high amount of K (0.88 %) in ionic form, which upon application to soil readily builds up K. Solubility of the nutrient increased with increase in organic matter content in the soil. This is in line with the findings of Savini et al. [6].

3.3 Effect on Available Micronutrients

The range of micronutrient cations rose somewhat with the addition of distillery spent wash (DSW) and gypsum, going from 4.80 to 6.85 mg kg^{-1} of Fe, 8.60 to 10.43 mg kg^{-1} of Mn, 0.64 to 0.88 mg kg^{-1} of Zn, and 1.10 to 1.42 mg kg^{-1} of Cu. Increased availability in DSW treated soils may result from direct DSW contribution as well as solubilization and chelation effects of DSW-supplied organic matter. Gypsum was added, which caused the soil's pH to drop. As Zn $(OH)_2$ precipitation diminishes due to a drop in pH, availability rises. With organic ligands, micronutrients are known to form chelates that are comparatively stable and reduce their sensitivity to adsorption, fixing, or precipitation. The accumulating amount of these metallic cations notably increased with an increased level of spent wash. The results of the present investigation are also in agreement with the findings Valliappan et al. [1].

Table 1. Effect of ameliorated alkali water and soil amendments on soil exchangeable cation of post-harvest soil

Treatments	Exch. Ca (c mol(p^+) kg^{-1}				Exch.Mg(c mol(p^+) kg^{-1}				Exch.Na(c mol(p^+) kg^{-1}				Exch.K(c mol(p^+) kg^{-1}			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	9.20	9.30	8.20	8.90	5.06	5.18	5.01	5.08	2.54	2.18	4.00	2.91	0.21	0.26	0.18	0.22
M_2	9.17	9.35	8.22	9.09	5.08	5.20	5.03	5.10	2.44	2.00	3.84	2.76	0.26	0.52	0.29	0.36
M_3	9.17	9.30	8.21	8.89	5.08	5.10	5.03	5.07	2.64	2.20	4.12	2.99	0.17	0.35	0.12	0.21
Mean	9.18	9.31	8.20.	8.96	5.92	6.05	5.02	5.03	2.54	2.13	3.99	2.88	0.21	0.38	0.20	0.26
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SE d	0.09	0.11	0.19	0.21	0.09	0.08	0.13	0.15	0.05	0.03	0.16	0.10	0.06	0.10	0.01	0.02
CD (0.05)	NS	0.27	NS	NS	NS	0.20	NS	NS	0.16	0.09	0.36	0.22	0.01	0.02	0.02	0.04

Main plot (Irrigation Treatment):M_1: Drip irrigation with gypsum treated water, M_2: Drip irrigation with spent wash treated water, M_3: Drip irrigation with untreated alkali water
Subplot: (Soil treatment): S_1: Soil application of gypsum @ 50% GR, S_2: One time application of distillery spent wash @ 5 lakh litter ha^{-1} (90,000 L), S_3: No amendments

Table 2. Effect of ameliorated alkali water and soil amendments on available N, P and K content of post-harvest soil

Treatments	Available N (kg ha^{-1})				Available P (kg ha^{-1})				Available K (kg ha^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	208	300	170	226	16.8	20.4	15.6	17.6	175	905	161	414
M_2	216	311	174	233	17.2	21.5	15.9	18.2	182	928	165	425
M_3	198	297	167	220	16.5	19.8	15.4	17.2	167	891	158	405
Mean	207	302	170	226	16 .8	20.6	15.6	17.7	175	908	161	415
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SE d	1.07	1.72	2.97	4.74	0.10	0.24	0.29	0.65	0.95	1.53	2.84	4.28
CD (0.05)	2.84	4.79	6.45	10.30	0.29	0.67	0.64	1.42	2.65	4.26	6.17	9.30

Main plot (Irrigation Treatment):M_1: Drip irrigation with gypsum treated water, M_2: Drip irrigation with spent wash treated water, M_3: Drip irrigation with untreated alkali water
Subplot: (Soil treatment): S_1: Soil application of gypsum @ 50% GR, S_2: One time application of distillery spent wash @ 5 lakh litter ha^{-1} (90,000 L), S_3: No amendments

Table 3. Effect of ameliorated alkali water and soil amendments on micronutrient cation Fe, Mn, Cu and Zn content of post-harvest soil

Treatments	Fe (mg kg^{-1})				Mn (mg kg^{-1})				Cu (mg kg^{-1})				Zn (mg kg^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	5.60	6.72	5.16	5.82	9.24	10.31	8.72	9.42	0.84	0.86	0.80	0.83	1.21	1.35	1.20	1.25
M_2	5.71	6.85	5.10	6.25	9.45	10.43	8.75	9.54	0.85	0.88	0.79	0.84	1.27	1.42	1.17	1.28
M_3	5.32	6.15	4.80	5.36	8.70	8.80	8.60	8.60	0.72	0.75	0.64	0.70	1.19	1.21	1.10	1.16
Mean	5.54	6.60	5.28	5.83	9.13	9.83	8.69	9.12	0.80	0.83	0.74	0.79	1.22	1.32	1.15	1.23
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SE d	0.06	0.03	0.17	0.09	0.04	0.07	0.12	0.21	0.03	0.01	0.01	0.03	0.02	0.01	0.08	0.05
CD (0.05)	0.18	0.09	0.38	0.21	0.12	0.22	0.27	0.47	0.01	0.03	0.04	0.07	0.08	0.05	0.19	0.11

Main plot (Irrigation Treatment):M_1: Drip irrigation with gypsum treated water, M_2: Drip irrigation with spent wash treated water, M_3: Drip irrigation with untreated alkali water
Subplot: (Soil treatment): S_1: Soil application of gypsum @ 50% GR, S_2: One time application of distillery spent wash @ 5 lakh litter ha^{-1} (90,000 L), S_3: No amendments
Main plot (Irrigation Treatment):M_1: Drip irrigation with gypsum treated water, M_2: Drip irrigation with spent wash treated water, M_3: Drip irrigation with untreated alkali water
Subplot: (Soil treatment): S_1: Soil application of gypsum @ 50% GR, S_2: One time application of distillery spent wash @ 5 lakh litter ha^{-1} (90,000 L), S_3: No amendments.

4. CONCLUSION

The study concluded that one time application of distillery spent wash @ 5 lakh litter ha^{-1} along with drip irrigation of gypsum bed treatment water can be effectively used as an amendment for reclamation of sodic soil and for getting higher yield of cotton.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/90059