Original Research Article

Influence of ameliorated alkaline water and soil amendments on soil properties, growth and yield of hybrid cotton in sodic soil under drip irrigation

ABSTRACT

Field experiment was conducted 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. 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 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 conducted in the strip-plot design with four replications. The amendments application either through irrigation water (or) through soil significantly reduced the pH of post-harvest soil. The maximum reduction in pH was recorded in spent wash applied plots (7.51) followed by gypsum applied plots (7.77) and control (8.73). Slight increase in EC with spent wash treated plots was observed due to increase in amount of soluble salt. A decrease in ESP of 0.5 and 1.1 was recorded due to the drip irrigation with gypsum treated water and drip irrigation with DSW treated water respectively over control. Similarly, a decrease in ESP of 8.4 and 10.6 was recorded due to soil application of gypsum and DSW respectively over control. Application of amendments had significant influence on the exchangeable cation of the post-harvest soil especially the beneficial cations Ca, Mg and K. Application of amendments drastically reduced the exchangeable sodium content of soil. The organic carbon and availability of NPK in the post-harvest soil significantly increased due to application of amendments. The microbial population, enzyme activities were increased on reclamation over control. 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.

Key words*:* Sodicity, gypsum, distillery spent wash, ameliorated alkali water, drip irrigation.

1.INTRODUCTION

Food security concerns coupled with the scarcity of new productive land has put productivity enhancement of degraded lands back on the agenda of research and development. In India, nearly 9.38 million ha area is occupied by salt affected soils, out of which 5.50 million ha are saline soils and 3.77 million ha are alkali soils and in Tamil Nadu 3.5 lakh ha are sodic soil. Sodic soils can be reclaimed by different amendments which can be selected based on their availability and severity of problem. Gypsum is a common amendment for sodic soils reclamation because of its (i) moderate solubility, (ii) ability to replace sodium ion (Na^{+}) on the exchange sites with calcium ion (Ca^{2+}), and (iii) low cost and wide-spread availability. The scarcity of organic manures like FYM or compost and the problem in availability and cost of gypsum have limited the scope of using them for reclamation. So, it is necessary to develop cheap and locally available highly efficient sources for reclamation. One such possibility is the addition of an acidic by-product of distillery industry wastewater i.e., raw spent wash. Thus, current experiment was aimed to study the influence of ameliorated alkali water and soil amendments on soil properties, growth, and yield of hybrid cotton in sodic soil under drip irrigation.

2.MATERIAL 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.

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

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 physico –chemical properties

Application of amendments resulted in significant decrease in soil pH (Table 1). pH of the soil ranged from 8.80 to 7.45. The pH declined from 8.73 in control (S_3) to 7.77 and 7.51 due to soil application of gypsum @ 50 % GR (S_1) and one time application of distillery spent wash @ 5 litter ha^{-1} (S_2) application, respectively. The reduction in soil pH was attributed to displacement of exchangeable Na by the calcium ion of gypsum and subsequent formation of sodium sulphate which get leached out of soil through drainage. Decrease in soil pH with DSW was attributed to acidic nature of raw spent wash (pH 3.8) which might have solubilized the native calcium carbonate and released free calcium ions and other calcium bearing minerals to the soil. In addition, the spent wash has calcium to an extent of 2600 mg L^{-1}. Results obtained in this study are in conformity with the findings of (Mohammed Haroon, 2004 and Mahindra, 2007).

The EC of the post-harvest soil varied from 0.45 to 1.09 dSm^{-1}. Among the soil treatments, one time application of distillery spent wash @ 5 lakh litter ha^{-1} (S_2) registered the highest EC (1.03 $dSm^{-1)}$ whereas the control (S_3) recorded the lowest EC (0.23 dSm^{-1}). The increase in the soluble salt content in the gypsum amended plots might be attributed to the chemical reactions of gypsum in the soil rendering them to more soluble sulphate of sodium. Significant reduction in the soil exchangeable sodium percentage was noted due to application of amendments. The decrease in soil ESP with addition of amendments may be attributed to increased Ca in soil solution as a result of addition of gypsum and organic sources which promoted Na displacement and its subsequent removal during irrigation to lower soil layers. An increase of 0.14 percent of organic carbon was observed with drip irrigation with spent wash treated water (M_2) application over the control**.** The usefulness of DSW as a valuable organic amendment on account of its high organic carbon content has been reported by several workers (Nehra and Hooda, 2002 and Ramaswamy, 1999).

3.2 Effect on soil exchangeable cation

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 (Table 2). The acidic nature of raw spent wash (pH 3.8) might have solubilized

native free lime which released Ca, Mg in free ionic forms which might have also contributed for increased Ca, Mg on exchange sites with the replacement of exchangeable sodium. Similar observations were also reported by Baskar *et al*. (2003) that application of raw spent wash increased the Ca and Mg contents of soil. Application of concentrated form of spent wash helped in greater exchange of sodium by calcium and subsequent leaching with good quality water replaced the sodium from the exchange sites. There was an increase in the content of exchangeable K with addition distillery spent wash due to composition of applied organic amendments (Ahmed *et al.*, 1988 and Muhammad and Khattak, 2009).

3.3 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 3). 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 (Pramer and Sharma, 2002). The effect 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.

3.4. Effect on available micronutrients

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. In DSW amended soils, the increased availability might be due to direct contribution from the DSW as well as solubilization and chelation effect of organic matter supplied by the DSW. Application of gypsum decreased the soil pH. Decrease in pH, decreases the Zn precipitation as $Zn(OH)_2$ and hence the availability increases. Micronutrients are known to form relatively stable chelates with organic ligands which decrease their susceptibility to adsorption and fixation or precipitation.

3.5. Effect on soil biological properties

Application of amendments significantly increased the soil microbial population and enzyme activates. The Bactria population ranges from 31 to 52 × 10^6 CFU g^{-1} , fungi 4.1 to 6.8 ×10^3 CFU g^{-1} and 3.4 and 5.10 × 10^2 CFU g^{-1} . An increase in nutrient content supplied by DSW might have increased the microbial population of the post-harvest soil. Enzyme activity in soil is an indirect indication of the microbial activity, which is directly correlated with soil microbial population. The higher soil enzymes activities were also maintained with 50 time's diluted effluent irrigation. The results of the experiments conducted by Kundu *et al*. (2001) revealed that there was no adverse effect of soil application of post methanated distillery on microbial population *vis-vis* urease activity in the soil.

3.6. Effect on plant growth parameter

The results of the field experiment revealed that application of irrigation water treatments and soil treatments significantly increased all the growth and yield parameters of cotton viz., Plant height, leaf area index, and monopodia branches per plant, length of sympodial branches per plant and cotton yield. 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 773.3 and 973.3 kg ha^{-1} was recorded due to soil application of gypsum and DSW respectively over control. While considering the overall effect, soil application of DSW along with gypsum bed treated water found to be the best (3015 kg ha^{-1}) when compared to other treatment combination. Among the amendments, highest yield (2685 kg ha^{1}) was recorded in the DSW applied treatments owing to their higher nutrient content along with high organic matter which would have caused favorable soil properties, higher nutrient availability in the soil, facilitating higher amount of nutrient absorption and translocation ultimately resulting in higher seed cotton yield. The reduction in pH and creation of favorable microclimate, increased availability of essential nutrients which in turn increased the yield in Gypsum applied plots.

3.7. Effects on nutrient uptake by cotton

Results (Table 7) showed that application of amendments caused significant increase in N, P and K uptake by cotton. The N uptake ranged from 53.7 to 125.7 kg ha^{-1} . The highest N uptake (103 kg ha^{-1}) was registered in the treatment drip irrigation with gypsum treated water (M_1) and lowest (73.9 kg ha^{-1}) in the control (M_3) treatment. The drip irrigation with gypsum treated water (M_1) and drip irrigation with spent treated water (M_2) application showed an increased N uptake of 29.1 and 22.2 kg ha^{-1} respectively over the control. The highest total N uptake was observed in DSW applied plots might be due to nitrogen contribution from the DSW. Application of amendments also caused significant increase in P uptake which ranged

from 8.82 and 27.5 kg ha^{-1} Application of drip irrigation with spent treated water (M_2) recorded highest P uptake (23.16 kg ha^{-1}) followed by drip irrigation with gypsum treated water (M_1) (21.43 kg ha^{-1}) and control recorded the lowest (13.10 kg ha^{-1}). Patil *et al.* (2000) noticed significant increase in P uptake (2.18 g pot^{-1}) by the application of spent wash @ 50 m^3 ha^{-1} over control (0.66 g pot^{-1}). Application of DSW and Gypsum enhanced K uptake in cotton plants. Drip irrigation with gypsum treated water (M_1) showed highest K uptake (112.9 kg ha^{-1}) followed by of drip irrigation with spent wash treated water (105 kg ha^{-1}) and control (80.3 kg ha^{-1}). The treatment receiving soil application of distillery spent wash @ 5 lakh litter ha^{-1} (S_2) and absolute control (S_3) showed maximum K uptake (128.5 kg ha^{-1}) and minimum K uptake (71.4 kg ha^{-1}) respectively. Joshi *et al.* (1996) also recorded significantly higher uptake of K in the treatment receiving spent wash @ 25000 liters ha^{-1} and attributed it to the increased availability of K from spent wash.

4.CONCLUSION

The present investigation concludes 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.

REFERENCES

1. Baskar, M., C. Kayalvizhi, and M. Subash Chandra bose, 2003, Eco Friendly utilization of Distillery Effluent in Agriculture- A Review. Agric. Rev., 24:16-30.

2. Joshi, H. C., H. Pathak, A. Choudhary and N. Kalra. 1996. Distillery effluent as a source of plant nutrients. Fert. News., 41: 41 – 47

3. Kundu, S., Biswas, A. K., Saha, J. K., Raman, S., Mohan singh and aharya, C. L., 2001, Urease activity and urea hydrolysis in a Typic Haplustert as affected by post-methanated spentwash application**.** J. Indian Soc. Soil Sci., 49: 210-212.

4. Mahendra, A. C. 2007. Studies on reclamation of sodic soils through distillery spent wash. *M.Sc., Thesis***,** University of Agricultural Sciences, Dharwad.

5. Mohamed haroon, A.R., and Subash chandra bose, M., 2004, Use of distillery spent wash for alkali soil reclamation, treated distillery effluent for fertigation of crops. Indian farming, March**:** 48-51.

6. Nehra, A. S. and I. S. Hooda. 2002. Influence of integrated use of organic manures and inorganic fertilizers on lentil &mungbean yields and soil properties. *Res. on Crops.* 3(1): 11-16

7. Patil**,** G. D., S. M. Pingat and Yelwande. 2000. Effect of spentwash levels on soil fertility, uptake, quality and yield of Fodder Maize. J. Maharashtra Agri. Univ.,**25**: 168-170.

8. Pramer, D. K. and V. Sharma. 2002. Studies on long-term application of fertilizers and manure on yield of maize-wheat rotation and soil properties under rain-fed conditions in Western-Himalayas**.** J. Ind. Soc. Soil Sci., **50:** 311-312.

9.Ramaswamy, P. P. 1999. Recycling of agricultural and agro-industry waste for sustainable agricultural production. J. Indian Soc. Soil Sci., 47(4): 661–665.

Table.1 Effect of ameliorated alkali water and soil amendments on soil physic-chemical properties of post-harvest soil

Treatments	pH				EC (dSm^{-1})				ESP (%)				Organic carbon (%)			
	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	7.76	7.50	8.75	8.00	0.60	1.04	0.48	0.70	14.8	12.7	23.2	16.9	0.52	0.70	0.42	0.54
M_2	7.70	7.45	8.65	7.93	0.75	1.09	0.54	0.79	14.2	11.8	22.6	16.2	0.71	0.80	0.44	0.65
M_3	7.85	7.60	8.80	8.08	0.50	0.98	0.45	0.64	15.5	13.3	23.5	17.4	0.48	0.68	0.39	0.51
Mean	7.77	7.51	8.73	8.00	0.61	1.03	0.23	0.71	14.8	12.6	23.1	16.7	0.57	0.72	0.41	0.56
	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	0.12	0.08	0.33	0.23	0.01	0.02	0.05	0.22	0.27	0.23	0.76	0.65	0.01	0.01	0.04	0.05
CD (0.05)	NS	0.23	NS	NS	0.05	0.06	0.12	0.48	0.76	0.64	1.66	1.42	0.04	0.05	0.09	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

Table 2. 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 3. 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 4. 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

Table 5. Effect of ameliorated alkali water and soil amendments on bacteria, fungi and Actinomycetes population of post-harvest soil

Treatments	Bacteria ($\times 10^6$ CFU g^{-1})				Fungi ($\times 10^3$ CFU g^{-1})				Actinomycetes ($\times 10^2$ CFU g^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	35.2	51.6	32.2	39.6	5.1	6.2	4.9	5.4	3.8	4.6	3.8	4.06
M_2	40.8	52.2	34.4	42.4	6.1	6.8	5.2	6.03	4.8	5.10	4.3	4.7
M_3	33.2	45.6	31.0	36.6	4.4	4.2	4.1	4.23	3.8	3.6	3.4	3.6
Mean	36.4	49.8	32.5	39.5	5.13	5.73	4.73	5.22	4.1	4.43	3.83	4.12
	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	0.07	0.06	0.19	0.55	0.03	0.02	0.10	0.08	0.06	0.03	0.17	0.11
CD (0.05)	0.20	0.19	0.43	1.20	0.10	0.08	0.23	0.19	0.18	0.11	0.38	0.25

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 6. Effect of ameliorated alkali water and soil amendments on growth attributes

Treatments	Plant height (cm)				No.of .boll /plant				Dry matter production (kg ha^{-1})				Seed cotton yield (kg ha^{-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	97.0	96.2	67.1	87.4	145.6	168.3	87.3	118.5	8611	9828	6023	8159	2778	3015	1948	2580
M_2	96.4	98.3	66.0	86.2	120.7	154.5	105.5	126.9	7830	9161	5322	7437	2610	2881	1780	2423
M_3	79.9	85.1	63.0	76.0	130.7	122.6	102.7	118.7	6183	6998	4201	5794	2068	2160	1410	1879
Mean	91.5	92.7	65.3	83.2	126.9	148.4	98.5	121.1	7541	8662	5187	7130	2485	2685	1712	2294
	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	0.32	0.28	0.94	0.83	4.25	1.98	1.27	2.95	157	189	403	425	56.3	67.8	144	152
CD (0.05)	0.91	0.80	2.04	1.82	11.80	5.51	2.77	6.41	436	526	876	921	156	188	313	329

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 7. Effect of ameliorated alkali water and soil amendments on N, P and K uptake (kg ha^{-1})at harvest stage of cotton

Treatments	Total N uptake				Total P uptake				Total K uptake			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	110	125	76.0	103	22.3	27.5	14.4	21.43	111	145	82.7	112
M_2	101	120	67.5	96.1	21.9	27.4	20.2	23.16	102	139	74.5	105
M_3	78.5	89.5	53.7	73.9	16.6	13.9	8.82	13.10	82.5	101	57.1	80.3
Mean	96.5	111	65.7	91	20.2	22.9	14.5	19.23	98.5	128	71.4	99.4
	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	2.19	2.64	5.61	5.92	0.45	0.54	1.15	1.21	1.80	2.16	4.60	4.86
CD (0.05)	6.08	7.33	12.2	12.8	1.24	1.50	2.50	2.63	4.99	6.01	10.0	10.52

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