Madras Agric. J., 99 (10-12): 698-703, December 2012
https://doi.org/10.29321/MAJ.10.100173

Evaluation of Cropping Systems in Partially Reclaimed Sodic Soils of North Western Zone of Tamil Nadu

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Soil reclamation and cropping system evaluation experiments were conducted during September 2009 to September 2010. To evaluate the best amendments in the sodic soils of Mallasamudram series in Magudanchavadi block of Salem district, Tamil Nadu in two locations (L_1 and L_2) representing strongly sodic (pH <9.5) and very strongly sodic (pH >9.5) soils. Soil amendments such as gypsum, ferrogypsum, sugar factory pressmud and distillery spent wash were employed to reclaim the sodic soils. Three cropping systems viz., Rice – cotton – sesbania, Rice – chillies – sesbania and Rice – finger millet – sesbania were tested in the above reclaimed sodic soils and evaluated. Significant positive variations in soil quality parameters were recorded during post reclamation. The distillery spent wash @ 5 lakh litres ha^{-1} treated plot consequentially reduced the soil pH from 9.42 to 8.25 in L_1 and from 9.95 to 8.45 in L_2 as compared to all other amendments and reduced the ESP from 44.0 to 16.2 in L_1 and 70.0 to 22.0 in L_2 respectively. Application of distillery spent wash significantly improved growth, yield attributes, grain and straw yield of first season rice crop. The performance of cotton, chillies and finger millet as second crop after rice in the cropping system was apparent. The rice- finger millet- sesbania system proved better than the other cropping systems.

Key words: Distillery spent wash, gypsum, ferro gypsum, cropping system and partial reclaimed sodic soils

The total geographical area of India is 329 m.ha, out of which the net area under cultivation is 138 m.ha. The present population of the country is 121 million and the annual food grain production has been to a tune of 205 million tonnes. India's population is expected to cross 1400 million by 2025 A.D. On an average, the country has to raise the annual food production by 5 million tonnes from the existing 205 million tonnes to reach the food grain requirement of 301 million tonnes by 2025 A.D. If the present growth rates of agriculture and population continue, India may have to import 45 million tonnes of food grains by 2025 A.D. In order to cope with the food grain requirements of the increasing population, agricultural production has to be stepped up substantially. This can be done either by multiple cropping on the existing cultivated lands or by bringing the additional land area under cultivation. The possibility to increase the food grain production to the required extent by these two ways is very much limited in India. The only feasible alternative is to increase the cultivated land area by bringing the wastelands and problem soils under cultivation.

Agro Climatic Regional Planning (ACRP) is proposed for implementation in the entire country by National Planning Commission. Accordingly the country has been divided into 15 Agro Climatic Zones. Tamil Nadu comes under 10th agro climatic zone namely southern plateau and hills. The study area encompasses the districts of Dharmapuri, Salem and Namakkal under the North Western Agro Climatic Zone of Tamil Nadu. The Agro Climatic Zone is the ideal and common working unit of all agricultural developmental activities.

The experimental study region has considerable area of sodic soils to the extent of 26,279 ha. Any study to reclaim such a large extent of sodic soils will go a long way to convert wastelands into productive lands. If the reclamation studies combined with efficient cropping system identification and development, will certainly augment crop production further. The NWZ comes under agriculturally potential area, but the presence of considerable extent of salt affected soils hampered agricultural productivity so much so the salt affected soil farmers are poor. Thus, reclamation and evolving suitable cropping system is utmost necessary to improve the status of the farming community of this region. Hence, the present study was undertaken covering a specific zone.

Materials and Methods

A field experiment was carried out during September 2009 to September 2010 in the sodic soils of Mallasamudiram soil series of Magudanchavadi block. The experiments were taken up in two locations based on severity of sodicity namely strongly sodic (pH <9.5) and very strongly

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sodic (pH >9.5) soils. The selection of locations was based on the surface soil samples collected from different salt affected villages of North Western Zone of Tamil Nadu. The results of surface soil sample analysis revealed that the samples from Sankari and Tiruchengode Taluk of Salem and Namakkal districts recorded high range of sodicity. The profile studies also revealed the important basic properties of sodicity already established in Mallasamudram soil series and hence locations were selected in this soil series. The experimental soil had low available N (196 and 113 kg ha_{-1}), P (8.30 and 5.00 kg ha_{-1}) and medium available K (225 and 175 kg ha_{-1}) at both the locations. The soil amelioration treatments consisted of nine amendments *viz.,* T_1 : Gypsum, T_2 : Ferrogypsum, T_3 : Distillery spent wash @ 5 lakh litres ha^{-1}, T_4 : Pressmud @ 12.5 tonnes ha_{-1} , T_5 : Pressmud @ 6.25 t ha_{-1} + Green leaf manure 6.25 t ha_{-1} *(Delonix alata),* T_6: Pressmud @ 6.25 t ha_{-1} + Farmyard manure 6.25 t ha^{-1}, $T_{7:}$ Gypsum + Green leaf manure @ 6.25t ha^{-1} (*Delonix alata),* $T_{8:}$ Ferrogypsum + Green leaf manure @6.25t ha^{-1} *(Delonix alata)* and $T_{9:}$ Untreated control. The quantity of gypsum and ferrogypsum were calculated at 50 per cent of gypsum requirement.

The three cropping systems tested were S_1 - Rice - cotton - sesbania (354 days), S_2 - Rice – chillies – sesbania (350 days) and S_3 - Rice – finger millet – sesbania (294 days) . Rice variety CO 43 (139 days duration), cotton MCU 5 (165 days), chillies - K2 (161 days), finger millet - GPU 28 (105 days) and *sesbania* local (50 days) were used for the study. The experiment was laid out in randomized block design with three replications. All the nine treatment combinations were allotted at random to plots within each replication. During second and third crops there was no change in the allotment of treatments to different plots. Each treatment was continued and imposed in the same plot for all the three seasons. The calculated quantities of gypsum, ferrogypsum, distillery spent wash (DSW) and pressmud were applied either alone or in combination with farmyard manure (FYM) and green leaf manure (GLM) as per the treatment schedule to the respective plots. The powdered soil amendments were spread evenly on the surface of the plots and mixed thoroughly to a depth of 10 - 15 cm layer under submerged puddled condition. Water level was maintained at 10 cm for 48 hours and then drained to wash out salts. The process of impounding and draining water was repeated twice in order to leach out salts from soil. The pressmud treated plots were irrigated and kept under submergence for 25 days. The DSW @ 5 lakh litres ha_{-1} was applied to the respective plots. Then the plots were dug manually using spade and the field was allowed for sun drying for nine days. Then on tenth day of DSW application, the plots were impounded with water to 10 cm and water level was maintained for 24 hours and then drained out. The process of impounding water and draining was done twice before transplanting of rice. On the 18_{th} day after application of DSW rice seedlings were transplanted in the main field. Soil samples from these plots were drawn to estimate pH, EC, available N, P, K and micronutrients to ascertain the extent of reclamation and soil fertility status. The recommended dose of fertilizers for rice (150:50:50 N, P_2O_5 and K_2O kg ha^{-1}), cotton (80: 40: 40 N, P_2O_5 and K_2O kg ha^{-1}), chillies (75:35:35 N, P_2O_5 and K_2O kg ha^{-1}) and finger millet (60:30:30 N, P_2O_5 and K_2O kg ha_{-1}) were applied as urea, single super phosphate and muriate of potash. Planting was done with a spacing of rice 20 X 10 cm, cotton 75 X 30 cm, chillies 45 X 10 cm and finger millet 15 X 15 cm and other cultivation practices were normally followed as per crop production guide (CPG, 1998).

For recording observations a sample consisting of five rice plants were selected at random and tagged. Growth parameters viz., plant height, leaf area index (LAI), dry matter production (DMP) and yield attributes such as number of tillers $hill_{-1}$, number of grains $panicle_{-1}$ and thousand grain weight, grain and straw yield were recorded.

For cotton, plant height, leaf area index (LAI), number of monopodial, sympodial, number of fruiting points $plants_{-1}$ and seed cotton yield were recorded. LAI was estimated at 120 DAS using the formula suggested by Ashley *et al.,* (1963). For chillies, plant height, leaf area index (LAI), number of fruits $plant_{-1}$, biomass production and dry fruit yield $plant_{-1}$ were recorded. In finger millet, plant height, leaf area index (LAI), number of earhead m_{-2}, number of fingers $earhead_{-1}$, grain and straw yield were recorded. In sesbania plant height and biomass production were recorded.

Statistical analysis of the data on various characters was carried out by analysis of variance Panse and Sukhatme, (1978).

Results and Discussion

Growth parameters of rice

The results of the experiment revealed that at both the locations application of distillery spent wash (DSW) significantly influenced the rice growth parameters, yield attributes and yield namely plant height (82, 76.7 cm at L_1 and L_2 respectively), number of tillers $hill_{-1}$ (20, 17), LAI (4.64, 3.50), maximum number of panicle hill m^{-2} (574, 513 in L_1 and L_2), number of filled grains (37 and 33 grains $panicle_{-1}$) in L_1 and L_2, the maximum grain yield of 4418 and 3293 kg ha_{-1} and straw yield of 9063 kg ha_{-1} and 6533 kg ha^{-1} were recorded in L_1 and L_2 respectively. (Table 1a, 1b, 1c, 2a, 2b and 3a & 3b). The influence of DSW treatment on enhancing rice plant height might be due to neutralization of sodicity leading to favorable physico-chemical soil condition like aeration, water movement and hydraulic conductivity, improved pH and EC and overall improvement in soil fertility. The outstanding performance of DSW was not only in alleviating sodicity but also in build up of plant nutrient status by restoring better soil fertility. The results are in agreement with the findings of Sriramachandrasekaran (1994). Murugaragavan (2002) also reported that the involvement of certain growth promoting substances like IAA spray increased plant height, LAI and number of tillers in rice.

Table 1a. Effect of treatments on rice plant height (cm) at harvest

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	62	65	63	63.3	56	57	54	55.4
T_2	61	64	62	62.3	54	53	54	53.6
T_3	82	80	84	82.0	75	82	73	76.7
T_4	58	60	59	59.0	47	50	54	50.2
T_5	72	70	69	70.3	51	52	57	53.4
T_6	60	59	62	60.3	45	49	49	47.6
T_7	70	69	71	70.0	60	59	58	58.9
T_8	74	72	73	73.0	58	57	60	58.0
T_9	52	47	46	48.3	38	34	35	35.7
SEd	5	5	6		5	3	3	
CD (p=0.05)	12	11	14		11	8	6	

Table 1b. Effect of treatments on rice tiller number at harvest

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	15	14	15	14.8	13	13	13	13.0
T_2	15	14	16	15.0	12	13	12	12.4
T_3	21	20	19	20.0	17	16	18	17.0
T_4	10	12	14	12.2	8	10	11	9.5
T_5	16	17	18	17.0	10	12	12	11.4
T_6	12	11	13	11.9	9	9	10	9.3
T_7	16	19	19	18.0	14	15	15	14.6
T_8	18	19	20	18.6	14	15	15	14.6
T_9	9	9	9	9.2	7	7	7	6.9
SEd	1	2	1		3	1	2	
CD (p=0.05)	2	4	3		6	3	4	

Table 1c. Effect of treatments on rice LAI at 70 DAT

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	1.98	1.92	2.03	1.97	1.21	1.32	1.32	1.28
T_2	1.81	1.82	1.96	1.86	1.19	1.19	1.21	1.20
T_3	4.42	4.84	4.68	4.64	3.56	3.42	3.52	3.50
T_4	1.26	1.32	1.36	1.31	0.67	0.62	0.75	0.68
T_5	2.28	2.42	2.52	2.40	0.82	0.82	0.92	0.85
T_6	1.38	1.29	1.35	1.34	0.51	0.42	0.52	0.48
T_7	2.24	2.23	2.32	2.37	1.30	1.35	1.39	1.35
T_8	2.42	2.52	2.65	2.53	1.39	1.42	1.42	1.41
T_9	0.68	0.72	0.82	0.74	0.31	0.21	0.32	0.28
SEd	0.39	0.35	0.32		0.27	0.14	0.19	
CD (p=0.05)	0.84	1.02	0.69		0.59	0.31	0.40	

Influence of treatments on biometrics of cotton

The data recorded on cotton biometrics like growth parameters, yield attributes and yield in relation to the effect of different treatments are presented in Table 4a and 4b. The residual effect of reclamation treatments applied to previous rice crop revealed that the DSW treated plot exhibited significantly increased cotton plant height of 88 and 67 cm and higher LAI with the values of 4.57, 4.20 at boll bursting stage in L_1 and L_2, higher monopodial and sympodial branches plant $^{-1}$ and also registered significantly higher boll number plant^{-1} with values of 25 in L_1 and 19 in L_2, higher boll setting percentage in cotton with values of 48 in L_1 and 42 in L_2 and a boll weight of 3.32 g in L_1 and 3.10 g in L_2, higher seed cotton yield of 1120 kg ha^{-1} in L_1 and 910 kg ha^{-1} in L_2 respectively and superior over the rest of the treatments. The mean seed cotton yield was distinctly different under L_1 and L_2 respectively with the application of distillery spent wash @ 5 lakh liters ha^{-1}.

Table 2a. Effect of treatments on yield components number of panicles m^{-2} in rice

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	380	360	348	362.6	326	276	309	303.6
T_2	365	358	376	366.3	298	302	278	292.6
T_3	550	565	608	574.3	496	512	530	512.6
T_4	320	308	328	318.6	236	248	210	231.2
T_5	370	406	356	377.3	258	256	236	250.0
T_6	330	318	296	343.3	190	182	186	186.0
T_7	390	376	382	378.0	318	335	310	321.0
T_8	402	385	368	385.0	322	321	298	313.6
T_9	260	244	240	248.0	168	198	178	181.3
SEd	76	38	56		31	39	43	
CD (p=0.05)	163	82	119		66	83	91	

Table 2b. Effect of treatments on yield components number of filled grains panicle^{-1} in rice

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	27	25	28	26.7	22	26	23	23.7
T_2	24	24	25	24.4	25	23	26	24.6
T_3	39	35	36	36.7	36	32	31	33.3
T_4	22	24	22	22.5	19	16	19	17.9
T_5	29	28	33	29.8	20	22	19	20.3
T_6	22	21	24	22.2	15	13	16	14.7
T_7	31	30	28	29.5	24	22	25	23.4
T_8	31	32	34	32.4	22	23	27	24.3
T_9	16	14	17.4	15.6	10	8	10	9.2
SEd	4	4	5		4	4	4	
CD (p=0.05)	9	9	11		9	8	8	

Table 3a. Effect of treatments on rice grain yield (kg ha^{-1})

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	1890	1845	1940	1892	1190	1220	1250	1220
T_2	1820	1765	1850	1812	1160	1195	1210	1188
T_3	4450	4325	4480	4418	3350	3230	3300	3293
T_4	1265	1230	1290	1262	575	520	650	582
T_5	2290	2230	2325	2282	980	890	930	933
T_6	1230	1195	1255	1227	350	380	420	383
T_7	2175	2115	2210	2167	1220	1190	1260	1223
T_8	2460	2390	2505	2452	1260	1350	1300	1300
T_9	730	650	710	697	280	210	260	250
SEd	414	377	343		242	112	218	
CD (p=0.05)	878	800	728		513	237	463	

Table 3b. Effect of treatments on rice straw yield (kg ha^{-1})

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	3175	3020	3240	3145	1760	1850	1790	1800
T_2	2950	2840	3030	2940	1700	1640	1590	1643
T_3	9125	8865	9200	9063	6650	6420	6530	6533
T_4	1870	1770	1950	1863	860	710	920	830
T_5	4010	3970	4320	4100	1420	1275	1340	1345
T_6	1810	1730	1900	1813	520	490	610	540
T_7	3915	3760	3980	3885	1940	2010	1990	1980
T_8	4220	4040	4520	4260	1860	2080	2120	2020
T_9	1065	890	980	978	360	320	420	367
SEd	777	242	648		626	708	619	
CD (p=0.05)	1643	513	1374		1328	1501	1312	

Influence of treatments on biometrics of chillies

The data recorded on chillies biometrics are

Table 4a. Effect of treatments on cotton biometrics (L_1)

T. No.	Plant height (cm)	LAI	Mono podia plant-1	Sympodia plant-1	Bolls plant-1	Boll setting per cent	Boll weight (g)	Seed cotton yield (kg ha-1)
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	57	4.21	2.6	27	15	41	3.18	770
T_2	58	4.18	2.4	25	14	39	3.07	720
T_3	88	4.57	3.4	45	25	48	3.32	1120
T_4	58	4.15	2.6	29	14	40	3.11	750
T_5	61	4.20	2.8	31	17	43	3.22	830
T_6	61	4.17	2.6	27	15	42	3.16	790
T_7	67	4.32	3.0	32	17	44	3.42	875
T_8	65	4.25	3.2	30	18	45	3.28	915
T_9	45	3.48	2.0	17	5.0	21	2.76	462
SEd	7	1	0	3	2	7	0	106
CD (p=0.05)	15	2	0	8	4	1	0	225

Table 4b. Effect of treatments on cotton biometrics (L_2)

T. No.	Plant height (cm)	LAI	Mono podia plant-1	Sympodia plant-1	Bolls plant-1	Boll setting per cent	Boll weight (g)	Seed cotton yield (kg ha-1)
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	47	3.82	2.4	25	8.0	29	2.98	650
T_2	47	3.76	2.2	24	9.0	29	2.89	670
T_3	67	4.20	3.2	38	19	42	3.10	910
T_4	43	3.53	2.0	16	6.0	23	2.92	480
T_5	46	3.60	2.6	22	7.0	28	2.96	590
T_6	44	3.56	2.4	16	6.0	26	2.84	525
T_7	59	4.02	2.8	28	10	31	3.18	715
T_8	60	3.94	3.0	27	11	32	3.12	740
T_9	37	2.76	1.8	14	3.0	16	2.52	210
SEd	5	0	0	2	1	5	0.11	105
CD (p=0.05)	10	0	0	5	2	11	0.23	222

presented in Table 5a and 5b. Higher plant height was obtained in DSW (T_3) with 79 and 68 cm, number of branches were recorded 2.4 and 2.2, higher LAI of 1.55 in L_1 and 1.18 in L_2, more number of fruits plant^{-1} (34) in L_1 and 24 in L_2, dry fruit yield was significantly higher (810 kg ha^{-1} in L_1 and 650 kg ha^{-1} in L_2). There were distinct differences between L_1 and L_2 with regard to mean dry fruit yield of chillies between treatments.

Influence of treatments on the biometrics of finger millet

Among the amendment higher plant height in finger millet at harvest stage was observed under DSW treatment (T_3) Table 6a and 6b. This treatment was superior over the other treatments and recorded a higher plant height of 83 cm in L_1 and 77 cm in L_2, The LAI recorded at flowering stage was significantly higher (0.32 in L_1 and 0.31 in L_2,) higher number of tillers hill^{-1} of 6 in L_1 and 5 in L_2 were recorded at 60 DAT, more number of productive tillers m^{-2} of 130 in L_1 and 110 in L_2 and produced significantly higher number of fingers ear head^{-1} and no. of grain fingers^{-1} with the values of 6.3, 120 in L_1 and 6.2, 111 in L_2, higher grain and straw yield of 1960, 3080 kg ha^{-1} in L_1 and 1540, 2540 kg ha^{-1} in L_2 respectively. There was distinct difference on finger millet grain and straw yield between L_1 and L_2.This might be due to organic amendments that had residual or carry over

Table 5a. Effect of treatments on chillies biometrics - L_1

T. No.	Plant height (cm)	Branches (nos.)	LAI	Fruits plant-1 (nos.)	Dry fruit yield (kg ha-1)
T_1	50	2.3	1.01	28	580
T_2	51	2.2	1.06	28	565
T_3	79	2.4	1.55	34	810
T_4	49	2.1	0.75	24	540
T_5	51	2.2	0.80	26	595
T_6	47	2.2	0.75	26	555
T_7	55	2.4	1.23	30	610
T_8	53	2.4	1.17	30	650
T_9	43	1.8	0.68	19	335
SEd	2	0	0.1	2	98
CD (p=0.05)	5	0	0.2	5	208

Table 5b. Effect of treatments on chillies biometrics - L_2

T. No.	Plant height (cm)	Branches (nos.)	LAI	Fruits plant-1 (nos.)	Dry fruit yield (kg ha-1)
T_1	43	1.5	0.69	17	450
T_2	44	1.4	0.81	16	390
T_3	68	2.2	1.18	24	650
T_4	35	1.3	0.57	16	280
T_5	39	1.4	0.64	16	320
T_6	36	1.3	0.59	16	305
T_7	46	1.9	1.03	19	480
T_8	46	1.8	0.98	18	465
T_9	29	1.2	0.26	12	240
SEd	3	0.1	0.1	1	75
CD (p=0.05)	8	0.3	0.2	2	159

effect on soil properties and on crop performances as well. Similar findings were reported by Meelu and Morris, (1986).

Influence of treatments on Sesbania aculeata biometrics

Table 6a. Effect of treatments on biometrics of finger millet - L_1

T. No.	Plant height (cm)	LAI	Tillers (No.)	Productive tillers m-2 (No.)	Fingers ear head-1 (No.)	Grains fingers-1 (No.)	Grain yield (kg ha-1)	Straw yield (kg ha-1)
T_1	67	0.29	4	96	5.9	105	1270	1750
T_2	68	0.28	4	94	5.7	102	1195	1620
T_3	83	0.32	6	130	6.3	120	1960	3080
T_4	64	0.25	4	98	5.9	98	1230	1820
T_5	65	0.27	4	109	5.7	103	1350	2060
T_6	62	0.27	4	105	5.7	100	1290	1980
T_7	71	0.30	5	112	6.0	108	1525	2067
T_8	72	0.31	4	120	5.9	113	1670	2200
T_9	58	0.21	3	80	4.4	85	780	1090
SEd	3.3	0.09	1	12	0.8	11	172	272
CD (p=0.05)	7.1	0.19	2	26	1.7	24	365	578

Table 6b. Effect of treatments on biometrics of finger millet - L_2

T. No.	Plant height (cm)	LAI	Tillers (No.)	Productive tillers m-2 (No.)	Fingers ear head-1 (No.)	Grains fingers-1 (No.)	Grain yield (kg ha-1)	Straw yield (kg ha-1)
T_1	59	0.27	4	98	4.9	95	1060	1520
T_2	55	0.26	3	95	4.9	90	990	1440
T_3	77	0.31	5	110	6.2	111	1540	2540
T_4	54	0.21	3	86	4.4	89	760	1030
T_5	57	0.25	3	92	4.7	91	870	1220
T_6	56	0.22	3	88	4.7	89	825	1090
T_7	64	0.29	4	103	5.3	100	1190	1680
T_8	61	0.27	4	107	5.5	103	1270	1770
T_9	46	0.19	3	79	4.1	77	580	800
SEd	8	0.02	4	6.7	0.6	17	116	208
CD	18	0.05	9	14.2	1.3	37	246	440

The effect of reclamation treatments applied to previous rice crop revealed that the DSW (T_3) exhibited significantly increased plant height of 153 cm and 132 cm in L_1 and L_2, significantly higher biomass yield of 14.5 t ha^{-1} in L_1 and 10.7 t ha^{-1} in L_2 respectively(Tables 7a and 7b). There was distinct difference between L_1 and L_2 with regard to biomass yield of *Sesbania aculeata*. The outstanding performance of DSW, not only in alleviating sodicity but also in building up of plant nutrient status by restoring better soil fertility is exhibited in the present study. The absence of harmful substances (particularly Na in sodic soils) that interfere with the movements of nutrients in balanced amount into roots is ensured and more of root proliferation through improved soil physical conditions is the possible reasons for the favorable effect of spent wash. Similar findings were reported by Rajukkannu *et al*. (1996). Tripathi (1998) also reported that cropping sequence comprising rice in kharif, wheat in rabi and sesbania in summer were more beneficial in Indo-Gangetic plains.

Rice equivalent yield

Rice yield equivalent and total energy output will be an acceptable denominator for assessing the performance of the different cropping systems (Table 8a, 8b and 8c). By this parameter, S_1 system in both the locations was superior and attributable to inclusion of component crops having high market price of produce. S_1 system under DSW treatment in L_1 and L_2 out yielded higher rice equivalent followed by S_2 and S_3 sequences. S_1 sequence in terms of rice equivalent yield recorded 93 and 73 q ha^{-1} in L_1 and L_2 respectively under DSW treated plot.

Table 7a. Effect of treatments on plant height of sesbania (cm)

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	95	107	113	105.0	87	78	83	82.7
T_2	93	102	111	102.0	76	81	79	78.7
T_3	144	153	161	152.7	132	126	137	131.7
T_4	98	76	83	85.7	58	60	70	62.7
T_5	114	92	90	98.7	65	67	75	69.0
T_6	94	83	86	87.7	61	63	65	63.0
T_7	110	123	127	120.0	92	87	97	92.0
T_8	106	111	119	112.0	87	84	93	88.0
T_9	58	52	63	57.7	38	41	45	41.3
SEd	7	11	9		11	5	6	
CD (p=0.05)	16	23	20		24	12	12	

Table 7b. Effect of treatments on biomass yield of sesbania (t ha^{-1})

T. No.	Location - 1				Location - 2			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	8.4	8.0	9.5	8.6	7.6	7.0	8.2	7.6
T_2	8.2	7.9	9.5	8.5	7.3	6.8	7.8	7.3
T_3	15	12.8	15.7	14.5	10.5	9.8	11.8	10.7
T_4	7.9	8.1	9.4	8.5	5.7	4.9	5.9	5.5
T_5	8.5	8.7	10.5	9.2	6.4	6.5	6.8	6.3
T_6	8.1	8.2	9.7	8.7	6.0	5.6	6.1	5.9
T_7	10.4	9.4	12.4	10.7	8.2	7.7	9.3	8.4
T_8	10.6	9.5	12.8	10.9	8.0	8.2	9.5	8.6
T_9	5.8	5.4	6.4	5.9	4.4	3.9	4.8	4.4
SEd	0.8	2.0	1.1		0.9	1.1	0.8	
CD (p=0.05)	1.7	4.3	2.5		1.9	2.5	1.7	

The other treatments also positively contributed to rice equivalent yield. Untreated control recorded lower rice equivalent yield. It was due to unreclaimed soil to sustain any viable cropping system. Though the yield of cotton and chillies was lower than finger millet during experimentation but due to higher market price of cotton and chillies more rice equivalent yield was obtained. Because of that, lower productivity in terms of rice equivalent yield was recorded in the case of finger millet grown after rice. This may be due to low market value of finger millet compared to cotton and chillies. Similar findings were also reported by Singh and Sharma (2002). Singh and Abrol (1988) also reported that among the cropping systems evaluated for Gomti river basin of Masodhao, Faizabad, rice-wheat and rice-mustard systems were found to be better in recording higher rice yield equivalents.

Table 8a. Effect of treatments on rice equivalent yield in cropping system (q ha^{-1}) – S_1

T.	Location - 1				Location - 2			
No.	rice	cotton	G.M	Total	rice	cotton	G.M	Total
T_1	23	26	1.1	50.4	14.0	17.7	0.98	32.7
T_2	22	24	1.08	47.1	13.8	18.0	0.94	32.7
T_3	54	37	1.81	92.8	41.1	30.7	1.3	73.1
T_4	15	25	1.04	41.0	6.89	14.7	0.76	22.4
T_5	28	28	1.19	57.2	11.7	18.0	0.84	30.5
T_6	15	26	1.07	42.1	4.20	15.7	0.79	20.7
T_7	27	29	1.33	57.2	18.2	23.7	1.08	43.0
T_8	30	31	1.40	62.4	16.3	22.7	1.06	40.1
T_9	9	15	0.84	24.8	3.28	9.7	0.61	13.6

Table 8b. Effect of treatments on rice equivalent yield in cropping system (q ha^{-1}) - S_2

T.	Location - 1				Location - 2			
No.	rice	chillies	G.M	Total	rice	chillies	G.M	Total
T_1	22.4	26.1	1.07	49.6	14.6	20.0	0.91	35.5
T_2	21.4	25.6	1.04	48.0	14.1	19.5	0.88	34.5
T_3	52.3	35.1	1.54	88.9	39.4	32.5	1.19	73.1
T_4	14.6	24.5	0.97	40.1	6.14	14.0	0.68	20.8
T_5	27.6	27.8	1.13	56.5	10.6	16.0	0.86	27.5
T_6	14.2	25.9	1.00	41.1	4.45	15.5	0.75	20.7
T_7	26.1	28.5	1.22	55.8	14.5	24.0	1.04	39.5
T_8	29.2	30.4	1.26	60.9	16.0	23.5	0.99	40.5
T_9	7.7	15.6	0.79	24.1	2.5	12.0	0.56	15.1

Table 8c. Effect of treatments on rice equivalent yield in cropping system (q ha^{-1}) - S_3

T.	Location - 1				Location - 2			
No.	rice	F.M	G.M	Total	rice	F.M	G.M	Total
T_1	23.7	17.2	1.15	42.1	14.9	14.0	1.01	29.9
T_2	22.5	16.2	1.09	39.8	14.2	13.1	0.98	28.3
T_3	54.4	26.0	1.77	82.2	40.1	21.7	1.42	63.2
T_4	15.5	16.8	1.06	33.4	7.7	10.3	0.78	18.8
T_5	29.8	18.2	1.22	49.2	10.1	11.8	0.89	22.8
T_6	15.0	17.5	1.02	33.5	5.0	11.3	0.80	17.1
T_7	27.4	20.2	1.33	48.9	15.2	15.8	1.08	32.1
T_8	31.0	22.1	1.37	54.5	15.9	15.2	1.11	32.2
T_9	8.4	10.8	0.86	20.1	3.1	8.0	0.66	11.9

Economic evaluation of cropping system

Gross, net return and BC ratio

Higher gross, net return and BC ratio were obtained with DSW (T_3) treatment (Table 9a, 9b and 9c). The gross, net return and BC ratio received was Rs. 58621, 32735, 2.1, 56646, 29802, 2.1 and 49356, 30316, 2.6 in L_1 and 43795, 17909, 1.7, 43898, 17054, 1.6 and 37935, 18895, 2.0 in L_2 under

S_1, S_2 and S_3 cropping sequences respectively. This was followed by T_8 in L_1 and T_7 in L_2 in all cropping systems tried. Among the cropping sequences, S_1 recorded higher gross, net return and BC ratio both in L_1 and L_2. Lower gross, net return and BC ratio were recorded in untreated control (T_9) in all the three systems both in L_1 and L_2.

Table 9a. Effect of treatments on economics of cropping system (Rs. ha^{-1}) - S_1

T. No.	Location - 1				Location - 2			
	G.R	COC	N.R	BC ratio	G.R	COC	N.R	BC ratio
T_1	30375	26096	4279	1.2	19750	26846	-7096	0.7
T_2	29329	26546	2783	1.1	19685	27746	-8061	0.7
T_3	58621	25886	32735	2.3	43795	25886	17909	1.7
T_4	22262	26136	-3874	0.9	13358	26136	-12778	0.5
T_5	32458	26136	6322	1.2	18319	26136	-7817	0.7
T_6	23247	26136	-2889	0.9	12395	26136	-13741	0.5
T_7	33795	26721	7074	1.3	25770	27471	-1701	0.9
T_8	35173	27171	8002	1.3	24017	28371	-4354	0.8
T_9	13891	24886	-10995	0.6	8086	24886	-16800	0.3

Table 9b. Effect of treatments on economics of cropping system (Rs. ha^{-1}) - S_2

T. No.	Location - 1				Location - 2			
	G.R	COC	N.R	BC ratio	G.R	COC	N.R	BC ratio
T_1	31588	27054	4534	1.2	21357	27804	-6447	0.8
T_2	30341	27504	2837	1.1	20742	28704	-7962	0.7
T_3	56646	26844	29802	2.1	43898	26844	17054	1.6
T_4	25579	27094	-1515	0.9	12498	27094	-14596	0.5
T_5	34929	27094	7835	1.3	16499	27094	-10595	0.6
T_6	25644	27094	-1450	0.9	12414	27094	-14680	0.5
T_7	34748	27679	7069	1.3	25398	28429	-3031	0.9
T_8	37848	28129	9719	1.4	24327	29329	-5002	0.8
T_9	12257	25844	-13587	0.6	9024	25844	-16820	0.4

Table 9c. Effect of treatments on economics of cropping system (Rs. ha^{-1}) - S_3

T. No.	Location - 1				Location - 2			
	G.R	COC	N.R	BC ratio	G.R	COC	N.R	BC ratio
T_1	25257	19250	6007	1.3	17921	20000	-2079	0.9
T_2	23900	19700	4200	1.2	16989	20900	-3911	0.8
T_3	49356	19040	30316	2.6	37935	19040	18895	2.0
T_4	19980	19290	690	1.0	11291	19290	-7999	0.6
T_5	29075	19290	9785	1.5	14181	19290	-5109	0.7
T_6	20182	19290	892	1.0	10253	19290	-9037	0.5
T_7	29374	19875	9499	1.5	21554	20625	929	1.0
T_8	32777	20325	12452	1.6	20206	21525	-1319	0.9
T_9	12023	18040	-6017	0.7	7102	18040	-10938	0.4

G.R = Gross return, COC = Cost of cultivation, N.R = Net return

From overall perspectives, S_3 system both in L_1 and L_2 was the most desirable system under optimal inputs. This system was high in objective functional value with a net return of Rs. 30316, 18895 ha$_{-1}$ with BC ratio of 2.6, 2.0 in L_1 and L_2 respectively, followed by S_1 and S_2 sequences. Even though higher grain yield were obtained in gypsum and ferrogypsum treatments, they were economically not viable because of increased cost and their application. Since the DSW under T_3 treatment was supplied free of cost from the distillery with greater nutrient content it is a viable proposition for the enhanced crop yield. Hence, T_3 treatment showed higher BC ratio compared to others. Considering economic viability, T_7 and T_8 were found promising under L_1. Under L_2, except DSW other treatments recorded lower net return and BC ratio due to high cost of chemicals. Similar findings were reported by Gangwar and Katyal (2001) and Singh and Sharma (2002).

It is concluded that the substantial area of sodic soils in North-West zone, can be economically utilized by suitable reclamation. The soils can be reclaimed by using DSW, gypsum and ferrogypsum, alone or in combination with organics. There has been overall improvement in soil physico-chemical properties by amendments application. Rice based cropping system can be profitably adopted in these reclaimed soils.

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Received: February 28, 2012; Revised: August 30, 2012; Accepted: December 21, 2012