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Ameliorative Effect of Different Amendments on Growth and Yield of Wheat in various Sodic Soil

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ABSTRACT: A pot house study was conducted at the Net House, Regional Research Station, AAU, Anand during *rabi* season of 2018-19 on Wheat (GW-496) as a indicator crop. Total 24 combinations of four amendments i.e. A_0 (control), A_1 (Gypsum @ 50% GR), A_2 (Vermicompost @ 4.0 t ha^{-1}) and A_3 (sulphur @ 50 kg ha^{-1}) and six soils (S1 to S6) were selected under Factorial CRD. The significantly highest plant height at 30, 60 DAS and harvest of wheat was recorded at all the three stages under vermicompost. Whereas, gypsum was found at par with sulphur. The wheat grain yield recorded under the treatment A_2 (Vermicompost @ 4.0 t ha^{-1}) was significantly highest (4.28 g pot^{-1}) over sulphur @ 50 kg ha^{-1}(A_3) and control (A_1), however, it was at par with A_1 (Gypsum @ 50% GR). The effect of gypsum (A_1) was found at par with sulphur (A_3). While, the significantly superior straw yield was noted under the influence of Sulphur (A_3) over other amendments and Control (A_0). The total yield of wheat was significantly affected by A_2: vermicompost over rest of amendments. The order of effectiveness of amendments in case of total yield was recorded as: vermicompost > gypsum > Sulphur. The total uptake of major and micronutrients were found highest under vermicompost application followed by the gypsum and sulphur. Initially it was challenging to find and collect the soils from different districts. At the time of growing season squirrels affected the wheat and we have sown the crop second time and then the green house was covered properly to protect from the birds and squirrels.

Keywords: Amelioration, amendment, sodic soil, Wheat.

INTRODUCTION

The ever increase in the world's *population* needs food productivity to step up within a few decades. Unfortunately, extensive areas of irrigated lands are unproductive, due to the sodicity and salinity problems in the soil profile occupied by root systems. So, for increasing food production we have to utilize the salt affected soil which is increasing day by day. Excess salt accumulations adversely affect soil physical, chemical and biological properties of soil results poor fertility status of salt affected soil. The sodic soils have pH > 8.5, ECe < 4 dSm^{-1} at 25 °C, ESP > 15 and SAR > 13. Amelioration of sodic and alkali soil primarily involves increasing Ca^{2+} on the cation exchange complex at the expense of Na^+. The replaced Na^+ is removed from the root zone through infiltrating water resulting from excessive irrigation(s). The combine application of inorganic-organic amendments like farm yard manure, vermicompost, castor cake, gypsum, elemental sulphur, sulphuric acid, etc. improved physical, chemical, and biological properties of soil. Wheat (*Triticum aestivum* L.) is a grass from family Graminae. It is a widely cultivated for its seed, a cereal grain which is a worldwide staple food. It is estimated that more than 35 per cent of the world's population depends on wheat. Wheat is important staple food crop in the world and second most important in the India after rice. In the production point of view the India rank second in world that is 12 per cent. In India area of wheat was 30.78 mha while production was 98.51 million tonnes, (Anon., 2020-21). The average wheat productivity of India was 3200 kg ha^{-1} (Anon., 2020-21), while in Gujarat wheat is grown over an area of 1.35 million hectares with an annual production and productivity is 3.65 million tonnes and 2730 kg ha^{-1}, respectively. Highest area and production is in Uttar Pradesh among all the wheat growing states. Major wheat growing states in India are Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, New Delhi and Bihar.

MATERIALS AND METHODS

The survey work was carried out in Anand and Kheda districts by Patel (2016) and Vaghela (2016), respectively, on the basis of 160 surface soil samples analysis, results indicated that 20 and 24 % soil samples categorised under sodic soils i.e. soil having pH > 8.5 and ESP > 15.0% and ECe < 4.0 dSm^{-1}. Six soils (3 from each district) were selected i.e. from Anand and Kheda district of middle Gujarat region. In survey work, Soil analysed for chemical parameters viz., pH, EC, SOC, available N, P, K, S, micronutrients (Fe, Mn, Zn, Cu), CEC, ESP, exchangeable Ca, Mg, K, Na , CO_3^{-2}, HCO_3^-, Cl^- and gypsum requirements. The pH, EC and ESP of initial soils were >8.5, < 4.0 dSm^{-1} and > 15 respectively. CEC ranged from 22.40 to 32.10 Cmol (P^+) kg^{-1}. A organic carbon ranged from 0.19-0.75 %, available P, available K and available S were from 19.31-85.87, 112.51-320.14 kg $ha^{-1}$and 8.13-12.54 mg kg^{-1} respectively. All the DTPA extractable micronutrients were medium to high.

Plant samples (grain and straw) were drawn at harvest of wheat for the further analysis. The oven dry plant samples were ground in stainless steel Wiley mill and preserved in polythene bags for analysis. The chemical analysis of the plant samples were carried out for nitrogen (N) content and also by digestion of 1 g of powdered plant samples with HNO_3: $HClO_4$ (4:1) di-acid mixture as per the procedure outlined by Jackson (1973). The acid extract of plant samples was used for analysis of total contents of P, K and micronutrients.

Uptake of nutrient (mg pot^{-1}) =

$$\frac{\text{Nutrient content (\%)} \times \text{Dry matter yield (mg pot}^{-1})}{100}$$

Methods used for chemical analysis of plant samples for total content of different nutrients as per standard methods presented in Table 1.

Table 1: Chemical methods used for Plant analysis.

Sr. No.	Parameters	Analytical method	Reference
1.	Nitrogen (N)	Kjeldahl'S method	Jackson (1973)
2.	Phosphorus (P)	Vanadomolybdo phosphoric acid yellow colour method	Jackson (1973)
3.	Potassium (K)	Flame photometry method	Jackson (1973)
4.	Sulphate-S	Turbidimetry	Williams and Stainberges (1959)
5.	Micronutrients (Fe, Mn, Zn and Cu)	Atomic Absorption Spectroscopy	Lindsay and Norvell (1978)

Table 2: The chemical properties of initial soil sample.

Chemical parameters	Soil types (Initial value)					
	S1	S2	S3	S4	S5	S6
pH (1:2.5)	8.78	8.88	8.90	8.84	9.05	8.65
EC (1:2.5) dSm^{-1}	0.80	0.82	0.98	0.85	1.01	0.68
Organic Carbon (%)	0.19	0.24	0.57	0.75	0.49	0.60
Available P_2O_5 (kg ha^{-1})	19.31	64.50	61.84	85.87	49.12	74.58
Available K_2O (kg ha^{-1})	112.51	116.20	320.14	165.10	185.30	130.32
Available S (mg kg^{-1})	8.13	12.54	10.64	11.85	6.60	10.50
CEC (Cmol (P^+)kg^{-1})	22.40	29.05	22.45	32.10	24.55	28.30
ESP	16.67	20.00	22.25	18.53	22.97	17.85
GR (t ha^{-1})	7.16	11.15	9.92	11.40	10.78	9.69
DTPA- Fe (ppm)	9.10	10.15	8.00	9.20	12.85	11.14
DTPA- Mn (ppm)	7.10	12.90	9.60	11.80	9.30	6.00
DTPA- Zn (ppm)	0.80	1.00	0.99	0.90	0.42	0.85
DTPA- Cu (ppm)	2.00	2.10	1.25	1.00	2.63	2.14

DTPA= Diethylenetriamine pentaacetate, ESP= exchangeable sodium percentage

Table 3: Effect on plant height, yield and grain nutrients content of wheat.

Sr. No.	Treatments	Plant height at harvest(cm)	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	Total yield (g pot^{-1})	Grain content Major Nutrients (%)				Grain content Micro Nutrients (mg kg^{-1})			
						N	P	K	S	Fe	Mn	Zn	Cu
Types of soil													
1.	**S1**	42.01	3.28	8.87	12.14	1.31	0.44	0.61	0.086	29.24	23.75	21.74	8.87
2.	**S2**	40.59	3.39	7.69	11.08	0.93	0.57	0.61	0.101	29.28	24.36	22.74	9.03
3.	**S3**	36.52	3.25	7.68	10.93	1.10	0.53	0.63	0.082	28.02	24.06	22.10	7.93
4.	**S4**	39.17	3.56	7.77	11.33	1.43	0.58	0.65	0.093	29.24	24.24	22.63	8.12
5.	**S5**	37.73	3.74	6.88	10.62	1.18	0.50	0.59	0.131	29.77	23.90	20.48	9.09
6.	**S6**	39.35	4.28	10.66	14.94	1.33	0.54	0.60	0.120	31.02	23.06	22.06	8.28
CD (P=0.05)		1.15	0.25	0.46	0.59	0.13	0.05	NS	0.005	0.19	0.30	0.30	0.21
Types of amendments													
1.	**A0 (control)**	33.72	2.55	4.71	7.26	0.83	0.40	0.50	0.055	28.06	23.03	21.12	8.13
2.	**A1 (Gypsum @ 50% GR)**	40.68	3.93	9.03	12.96	1.29	0.49	0.64	0.121	29.70	23.93	22.16	8.59
3.	**A2 (Vermicompost @ 4.0 t ha^{-1})**	41.88	4.05	9.99	14.05	1.69	0.71	0.75	0.088	30.43	24.87	22.54	8.93
4.	**A3 (sulphur @ 50 kg ha^{-1}).**	40.64	3.79	10.60	13.09	1.05	0.51	0.58	0.144	29.52	23.76	22.01	8.55
CD (P=0.05)		0.81	0.20	0.37	0.42	0.11	0.04	0.05	0.004	0.38	0.21	0.22	0.15
Interaction (S × A)		2.30	0.49	0.92	1.19	0.26	0.09	NS	0.010	NS	NS	NS	NS
CV%		3.57	8.41	6.75	6.11	13.22	11.33	11.47	6.12	2.23	1.54	1.70	3.06

Table 4: Effect of amendments on major and micronutrients uptake by wheat.

Sr. No.	Treatments	Yield (g pot^{-1})	Total uptake (mg pot^{-1})				Total uptake (mg pot^{-1})			
			N	P	K	S	Fe	Mn	Zn	Cu
Types of soil										
1.	**S1**		108.96	47.12	48.08	6.73	0.308	0.216	0.203	0.046
2.	**S2**		70.66	46.34	51.22	7.34	0.285	0.208	0.198	0.048
3.	**S3**		86.72	50.06	51.22	6.08	0.269	0.203	0.188	0.033
4.	**S4**		112.80	55.79	52.31	7.25	0.290	0.213	0.203	0.035
5.	**S5**		93.70	48.34	47.08	9.23	0.280	0.198	0.171	0.047
6.	**S6**		139.86	73.83	64.59	11.99	0.408	0.253	0.258	0.048
CD (P=0.05)			10.22	4.71	5.43	0.54	0.020	0.011	0.004	0.003
Types of amendments										
1.	**A0 (control)**		41.35	25.38	25.85	2.70	0.175	0.122	0.119	0.027
2.	**A1 (Gypsum @ 50% GR)**		112.75	54.81	57.24	9.99	0.337	0.237	0.224	0.046
3.	**A2 (Vermicompost @ 4.0 t ha^{-1})**		155.43	77.17	71.71	7.44	0.377	0.268	0.248	0.052
4.	**A3 (sulphur @ 50 kg ha^{-1}).**		98.95	56.97	55.35	12.27	0.338	0.234	0.222	0.046
CD (P=0.05)			7.23	3.33	3.84	0.39	0.012	0.008	0.008	0.002
Interaction (S × A)			20.45	9.42	10.86	1.09	0.034	0.023	0.022	0.006
CV%			12.20	10.71	12.59	8.19	6.798	6.481	6.634	8.768

RESULT AND DISCUSSION

Growth and yield of wheat affected by amelioration of soils by different amendments

Plant height: All the amendments showed significant effect on plant height of wheat at harvest as given in the Table 3. The significantly highest plant height (41.88 cm) recorded with the application of amendment A2 i.e. vermicompost @ 4.0 t ha^{-1} over other amendments and control also. The statistically equal effect of gypsum and sulphur was observed on plant height at harvest. It showed ameliorated effect of amendments in increasing plant height over control. As compared to control, vermicompost, sulphur and gypsum increased plant height of 24.19, 20.52 and 20.64 per cent, respectively. With regards to different sodic soils, S1 recorded significantly highest plant height of wheat crop at harvest. The significantly highest plant height (45.03 cm) was found due to interaction effect of treatment combination S1A2 though which was at par with S1A1, S2A1, S2A2, S4A2 and S2A3. While lowest in treatment S4A0 (29.20 cm), and was at par with S3A0. Vermicompost found most effective in increasing the plant height, which might have enriched the rhizosphere with macro and micronutrients besides replenishment of deficient nutrients in soil. Similar results were also observed by Patcharapreecha *et al*. (1990), they revealed that application of compost was the most effective followed by mulching compared to that of gypsum in reclaiming sodic soils. The increased nutrient availability due to vermicompost and might have increased the various endogenous hormonal levels in plant tissues, which might be responsible for enhanced yield and yield attributes. These results are in line with those reported by Kumar and Yadav (2008); Bafna *et al*. (2010). Vermicompost is the product of non-thermophilic biodegradation of organic material through the joint action of earthworms and microorganisms, contains plant growth promoting compounds and exhibits disease suppression properties in addition to being nutrient source and soil conditioner (Logsdon, 1994; Ersahin *et al.,* 2009). Azarmi *et al*. (2008) showed that addition of vermicompost @ 15 t ha^{-1} significantly increased contents of soil total organic carbon, total N, P, K, Ca, Zn and Mn substantially compared with control plots**.** The addition of vermicompost in soil resulted in decrease of soil pH. The physical properties such as bulk density and total porosity in soil amended with vermicompost were improved. Ezra John *et al*. (2022) founded that the highest plant height was shown under application of poultry manure in marigold at the application rate of 5 t ha^{-1}, followed by gypsum at 50% GR.

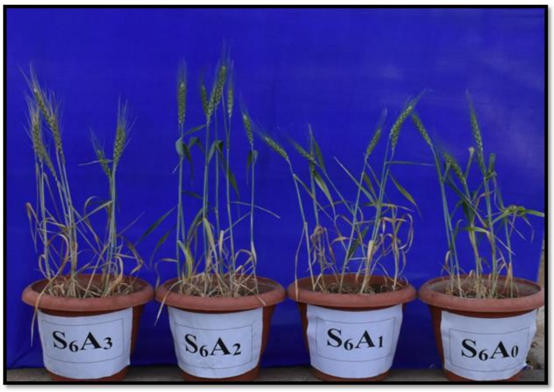

Plate 1. Plant height at harvest**.**

Grain and straw yield: The data shows that irrespective of soils, all the amendments had shown significant effect on grain and straw yield of wheat. The wheat grain yield recorded under the treatment A2 (Vermicompost @ 4.0 t ha^{-1}) was significantly highest, however, it was at par with A1 (Gypsum @ 50% GR), while lowest was recorded under A0 (Control). The effectiveness of amendments on wheat yield followed order as: Vermicompost > Gypsum = Sulphur. The addition of vermicompost @ 4 t ha^{-1} significantly increased grain yield of wheat by 58.8 % over control. With regards to different soils, the highest grain yield recorded in soil S6 (4.28 g pot^{-1}), while lowest was found in S3 (3.25 g pot^{-1}). The highest grain yield was recorded in S6A2 treatment combination which indicated the beneficial effect of vermicompost @ 4.0 t ha^{-1}, however, it was at par with interaction of S5A1 i.e. gypsum @ 50% GR.

Amongst amendments, vermicompost significantly increased grain yield of wheat over control. The beneficial effect of vermicompost in increasing wheat grain yield might be due to amelioration of rhizosphere and enriched with macro- and micronutrients besides replenishment of deficient nutrients in soil. The increased in plant height (Table 3) and soil available nutrients and decreased in soil pH and ESP favoured increasing in grain yield of wheat due to application of vermicompost. The similar results were reported by Ansari and Ismail (2008), as: sodic soil bioremediation was significant in plots treated with "vermiwash, tillage, green manure, mulch, earthworms and vermicompost" suggesting qualitative improvement in soil properties. The average yield of wheat and paddy crop cycle during the two years of trial showed a significantly greater response. The treatment where farmyard manure was applied at the rate of 20 t/ha in combination with 100% neutralization of RSC water through gypsum (10 t/ha) was obtained significantly maximum seed yield per plant (g), seed yield (q/ha), revealed by Choudhary *et al.* (2022).

The significantly superior straw yield was noted under the influence of A3 (Sulphur @ 50 kg ha^{-1}) amendment over other amendments, while lowest was recorded in A0 (Control). The order of effectiveness of amendments in case of straw yield was observed as: Sulphur > Vermicompost > Gypsum. The almost double straw yield recorded due to application of sulphur, vermicompost and gypsum over control. With resect to different sodic soils, highest straw yield recorded in soil S6 (10.66 g pot^{-1}) as in case of grain yield also, while lowest was found in S5 (6.88 g pot^{-1}), though, it was at par with S2, S3 and S4 soils. Interaction effect of soils and amendments was found to be significant on straw yield of wheat. The result thus indicated that the beneficial effect of amendment like vermicompost was more pronounced in soils having pH 8.65 and ESP 17.85 than other soils. The application of sulphur proved to be more efficient in increasing straw yield as compared to other amendments. This might be due to sulphur being acid former, which might have mobilized the native Ca^{+} of soils and enhanced the conversion of $CaCO_3$ into more soluble $CaSO_4$, $Ca(HCO_3)_2$, or $CaCl_2$ and reduced soil pH and ESP there by improved crop yield. Acids forming amendments have been reported more efficient in decreasing the soil pHs, ECe and ESP than gypsum (Ghafoor and Muhammad 1981).

N, P, K and S content in wheat grain: Among all the amendments, vermicompost treated soil at 4.0 t ha^{-1} showed highest grain N, P and K content, while lowest content were in control (0.83%). The effectiveness of amendments in enhancing N and K content in wheat grain showed as: vermicompost > gypsum > sulphur. In comparison to gypsum at 50% GR, the application of sulphur at 50 kg ha^{-1} was found more effective to in increasing P content in wheat grain over control. In case of different sodic soils, significantly the highest wheat grain N content i.e. 1.43 %. The data showed lowest grain N content (0.93%) was observed in soil S2 irrespective of amendments. Interaction of soil and the amendments had significant effect on N content in wheat grain. The highest N content in grain of wheat was recorded under S6A2 interaction (2.02 %), which was at par with S5A2 and S4A2 with N content of 1.85 and 1.78 %, respectively. The application of sulphur at 50 kg ha^{-1}, gypsum at 50% GR and vermin-compost when applied at 4.0 t ha^{-1} had significantly enhanced S content in wheat grain.

The highest S content (0.144%) was recorded due to sulphur as amendment followed by gypsum application (0.121%). Further, the data given in Table 3 shows that the highest S content (0.131 %) was recorded with S5 soil amongst other sodic soils. Interaction effect of S5A3 recorded the highest grain S content (0.173%) which was at par with S6A3, S4A3 and S6A1 treatments. The obvious reason behind increase in S content in wheat grain was due to sulphur supplemented on account of application of S containing amendment sulphur at 50 kg ha^{-1}.

Micronutrients content of grain: The grain micronutrients content were significantly influenced due to different amendments and data are presented in Table 3. Among all the amendments, soil treated with vermicompost at 4.0 t ha^{-1} showed the highest Fe, Mn, Zn and Cu content (30.43, 24.87, 22.54 and 8.93 mg kg^{-1}repectively) in wheat grain, while the lowest was in control. The effects of gypsum and sulphur on grain micronutrients content of wheat were comparable. With respect to soil types all micronutrietns were highest in different soils. Among the different soils, significantly the highest content of Zn, 22.74 mg kg^{-1} in wheat grain was recorded with soil S2; which was at par with S4 (22.63). In soil S5, the lowest Zn content of wheat grain was recorded with the value of 20.48 mg kg^{-1}. Soil S5 recorded the highest Cu content of 9.09 mg kg^{-1} being at par with S2 soil.

Total uptake of major nutrients by wheat: The increase in uptake of NPK by wheat due to vermicompost at 4.0 t ha^{-1} were highest than other amendments. The yield of straw and grain was also higher under this treatment. These results are in line of those reported by Kumar *et al*. (2014b). They reported that the higher NPK uptake by wheat was mainly due to enhancement in wheat yield due to treatments in sodic soil. The uptake of N increased because it was utilized for metabolism of various substances required for growth of plants which produced more dry matter.

The application of organic manures alone or along with inorganic fertilizer might have increased K uptake through favourable conditions created in soil for the uptake of nutrients. Like N, P and K - uptake also increased significantly with the application of organic manures alone or along with inorganic fertilizer. Similar results were also reported by Rani and Sukumari (2013); Yadav *et al*. (2005); Walia (2007) in wheat crop. The reduction in soil pH in soils treated with organic fertilizers would be attributed to organic acids produced as a result of degradation of organic compounds addition and CO_2 evolution in root rhizosphere besides microbial activity leading to H_2CO_3 formation and creating favorable environment for nutrients availability (Brady and Weil 2001). However, the data revealed that the application of sulphur at 50 kg ha^{-1} significantly increased total S uptake by wheat (12.17 mg pot^{-1}), followed by gypsum (9.99 mg pot^{-1}) and vermicompost (7.44 mg pot^{-1}).

In general, the available contents of soils were low initially i.e. below the critical level which favoured for the response to the application of sulphur. Further, sulphur containing compounds are acid forming materials which release sulphuric acid on oxidation in soil resulting a favourable condition for crop growth particularly in alkaline soils. This findings are in agreement with those reported by Singh *et al*. (1981); Ghafoor and Muhammad (1981), as acid or acid forming material like H_2SO_4, HCl, HNO_3, S could also be utilized as amendments, to mobilize native Ca^+ in calcareous soils and enhances the conversion of $CaCO_3$ into more soluble $CaSO_4$, $Ca(HCO_3)_2$, or $CaCl_2$. The results are in line with Ali *et al*. (2012) these reported that wheat grain yield was the maximum (4040 kg ha^{-1}) due to application of 50 kg S ha^{-1} which was higher by 26% over control.

Total uptake of micronutrients: The total micronutrients uptake by wheat were significantly affected with application of different amendments. The data are presented in Table 4. Shows that among the amendments, vermicompost applied at 4.0 t ha^{-1} showed the highest total Fe, Mn, Zn and Cu uptake by wheat (0.377, 0.268,0.248 and0.046 mg pot^{-1}respectively) while the lowest total uptake were in control. The order of effectiveness on total uptake of all the micronutrients by wheat was vermicompost >gypsum = sulphur. irrespective of amendments, the highest total Fe uptake by wheat was recorded in S6 (0.408 mg pot^{-1}), while the lowest was in S3 soil (0.269 mg pot^{-1}), which was at par with S2 and S5. The interaction effect of soil × amendment was found to be significant. The total uptake of micronutrients was higher in vermicompost, because the yield of wheat was higher under this treatment and also grain and straw content were recorded higher under vermicompost followed by gypsum and sulphur.

CONCLUSIONS

It can be concluded that the application of vermicompost @ 4.0 t ha^{-1} significantly ameliorate the sodic soils by decreasing pH and ESP and thereby increased the wheat yield, nutrients content and uptake by wheat. So, the vermicompost @ 4.0 t ha^{-1} found better for the amelioration of different sodic soils amongst studied amendment. The effectiveness of gypsum and sulphur were proved comparable in increasing the yield of wheat in sodic soils.

FUTURE SCOPE

— Research and breeding for expression of the relevant plant gens in the rhizosphere of important crops may also provide new management options for improving crop yield in sodic soils.

— Need to further evaluate the nutrient management in sodic soils.

— Crop rotation which give best result in sodic soils need to be assessed in future.

— There is a need to investigate salt specific sodic soil amendments.

Authors Contribution: Dr. K.C. Patel and Radha Chaudhary conceived of the presented idea. Radha Chaudhary performed the computations. Dr. K.C. Patel and Radha Chaudhary verified the analytical methods. Astha Pandey and Bhavik J. Prajapati encouraged and helped Radha Chaudhary to analyse various parameters in the laboratory. All authors discussed the results and contributed to the final manuscript.

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