Ameliorative effect of different amendments on nutrients availability in sodic soils

Abstract: A pot house experiment 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 four amendments i.e. A_0(control), A_1(Gypsum @ 50% GR), A_2(Vermi-compost @ 4.0 t ha^{-1})and A_3 (sulphur @ 50 kg ha^{-1}) and six soilstype (S1 to S6) were selected under Factorial CRD. Pot study results indicated that the soil amendments significantly decreased the pH, EC and ESP of sodic soils. The order of decrease in pH of sodic soils from 8.75 to 7.89 by application of amendments remained as: vermin-compost > sulphur > gypsum. The EC of sodic soils significantly decreased due to application of vermin-compost and gypsum by 20.48% and 10.84%, respectively over control. The application of vermin-compost, gypsum and sulphur significantly lowered down Exchangeable Sodium Percentage(ESP) from 18.45 to 12.44, 13.00 and 13.57, respectively, and the effect of gypsum was found at par with sulphur in decreasing soil ESP. Application of vermin-compost (4.0 t ha^{-1}) significantly influenced CEC (28.28 Cmol (P^+) kg^{-1}) over control (no amendment). Irrespective of amendments, soil S5 recorded the highest pH (8.39), EC (0.92 dSm^{-1}), ESP (16.48) and the lowest was in soil S6 (pH 7.99, EC 0.64 dSm^{-1}). The interaction of soil x amendment treatments showed significant effects on pH, EC and ESP of sodic soils. The application of amendments showed significant effect on available nutrients in soil after harvest of wheat and the highest OC (0.73%), available P_2O_5 (65.71 kg ha^{-1}), available K_2O (207.1 kg ha^{-1}) content in soil was recorded when vermin-compost applied at 4.0 t ha^{-1} followed by sulphur at 50 kg ha^{-1} and gypsum at 50% GR but available S (16.33 mg kg^{-1}) was recorded the highest due to sulphur application at 50 kg ha^{-1} followed by gypsum and vermi-compost.

Key words: amelioration, amendment, sodic soil, ESP, CEC

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" (Nisha *et al.*, 2018). "According to study, an area of 6.74 mha in India suffers from salt accumulation out of which 3.78 mha aresodic, while 2.96 mha are saline soils" (Anon.,2021)."Among different states, Gujarat rank first (22 lakh ha.) in area of salt affected soil, while alkali soils is 5.41 lakh ha" (Anon., 2021). "These soils are distributed in the districts of Kutch, Patan and Mahesana in north Gujarat, Anand, Ahmadabad and Kheda in middle Gujarat, Surendranagar, Rajkot, Amreli, Bhavnagar, Porbandar, Junagadh and Jamnagar in Saurashtra and Valsad, Surat and Bharuch districts of south Gujarat". (Anon., 2021).

"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, EC< 4 dSm^{-1} at 25 °C, ESP > 15 and SAR > 13.So, for increasing food production we have to utilize the salt affected soil which is increasing day by day. Reclamation has been proved to be an effective way to improve soil quality of salt affected soils. Theoretically, two steps are needed to perform sodic soil reclamation, the first step is removal Na+ from the cation exchange sites in the soil colloid, and the second step is leaching out the replaced Na+ in the plant root zone" (Tripathi *et al*.,2016). "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 irrigations" (Qadir *et al*., 2001)."The combine application of inorganic-organic amendments like farm yard manure, vermi-compost, castor cake, gypsum, elemental sulphur, sulphuric acid, etc. improve physical, chemical, and biological properties of soil. The biological amelioration methods which is using living or dead organic matter (crops, stems, straw, green manure, barnyard manure, compost, sewage sludge) have two beneficial effects on the alkali soils reclamation,- first is the improvement of the soil structure and permeability, thus enhancing salt leaching, reducing surface evaporation, and inhibiting salt accumulation in the surface layers; and the second is release of carbon dioxide during respiration and decomposition. For saline or sodic soils, the addition of organic matter (OM) can accelerate the leaching of Na, decrease the ESP and electrical conductivity (EC), and increase water infiltration, water-holding capacity, and aggregate stability" (Lax *et al.* 1994,: Qadir *et al.* 2001). So here in this study we have used different amendments to know the effect on reclamation of sodic soils.

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,pot study was carried out on selected six soilscategoriesto study the amelioration of sodic soils by using different amendments and its effect on soil properties and yield of wheat (*Triticumaestivum* L.). Results indicated that 20% from Anand and 24 % from kheda district 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. Experiment wasdesigned under Factorial CRD with 24 treatments and 3 replications.After harvest of the crop, pot wise soil samples were collected from approximately 20cm depth and air dried in laboratory. The air dried soil samples were pounded with wooden mortar and pestle. After pounding, the soils were sieved through 2 mm sieve and preserved in polythene bags properly labelled. The soil sample was analysed for the pH, EC, CEC, ESP, GR, organic C, available N, P_2O_5, K_2O and Micronutrients (Fe, Mn, Zn, Cu) as per standard methods.

Table 1: 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 2: Chemical Compositions of Amendments:

Amendments	N (%)	P (%)	K (%)	Ca %	Mg %	S (%)	Fe %	Mn %	Zn %	Cu %
Vermi-compost	1.12	0.33	0.80	2.28	0.41	0.20	0.45	0.02	0.06	0.007
Gypsum	-	-	-	24	-	16	-	-	-	-
Sulphur	-	-	-	-	-	90	-	-	-	-

Results and discussion:

Effect on pH

All the amendments significantly decreased the pH of soil(Fig.). A vermi-compost (4.0 t ha^{-1}) application significantly decreased the pH (7.89), followed by sulphur (50 kg ha^{-1}) and gypsum (50% GR)(Table 3). The order of decrease in pH of soil from 8.75 to 7.89 by application of amendments remained as: vermi-compost>sulphur> gypsum.Highest pH value was observed due to interaction effect of S_5A_0 treatments (no amendment) which was significantly decreased with application of amendments. "Formation of carbonic acid from CO2 produced during the decomposition of organic residues in soils is the main component responsible for decreasing pH" (M. Jalali *et al*., 2020)."Application of organic amendments leads to increased CO_2 partial pressure within soil profile, lowered soil pH value in soil solution and subsequently increased native $CaCO_3$ mineral dissolution and reduces the soil sodicity" (Li and Keren, 2009).

Effect on EC

Vermi-compost and gypsum significantly decreased the EC of sodic soils by 20.48% and 10.84%, respectively over control. There was no significant change in EC due to sulphur application (Fig. 2). Irrespective of amendments, soil S_5 recorded the highest EC (0.92 dSm^{-1}), while it was lowest in S_6 (0.62 dSm^{-1}), being at par with S1 (0.64 dSm^{-1}). Interaction effect of S_3A_3 and S_5A_3 combinations found significantly superior over others but was at par with $S_3A_0$and S_5A_0. "For saline or sodic soils, the addition of organic matter (OM) can accelerate the leaching of Na, decrease the ESP and electrical conductivity (EC), and increase water infiltration, water-holding capacity, and aggregate stability" (Lax *et al*., 1994; Qadir*et al*., 2001). "However, overall evaluation indicated that EC values of soils treated with organic fertilizers were below the EC value of soil with chemical fertilizer. This is possibly due to the fact that, unlike chemical fertilizers, organic fertilizers release nutrients more gradually as a result of degradation process and their chelating effect" (Gerke*et al*., 1999; Sharma and Banik, 2014).

Effect on ESP

Application of amendments significantly decreased the ESP of soils. The application of vermi-compost, gypsum and sulphur significantly lowered down ESP from 18.45 to 12.44, 13.00 and 13.57, respectively, the effect of gypsum was found at par with sulphur in decreasing soil ESP. However, all the amendments reclaimed soil by reducing the ESP below 15 (Fig. 3).With regards to different soils, it shows that soil S_5 recorded with highest ESP (16.48)(Table 3). Almost in all soils, the ameliorating effect of amendments were observed by reducing the ESP below 15 except soil S_5. Among above amendments vermi-compost was most efficient to decrease soil ESP, might be due to amendments alleviating the harmful effects of sodicity by replacing the Na^+ from exchange site, also after leaching of Na^+ from root zone, crop might also benefited by the improved physical properties of soil leading to more crop growth in these treatments and the result is at par with the finding ofHussain*et al.*, 2001,: Tzanakakis*et al.*, 2011, andMohamed *et al.*, 2012.

Effect on CEC

Application of vermi-compost (4.0 t ha^{-1}) significantly influenced CEC (28.28 Cmol (P^+) kg^{-1}) over control (no amendment). There were no significant effect of sulphur, gypsum was found at par with control indicating there were no effect of gypsum and sulphur on CEC of soils (Table 3). The increased in CEC of soil due to vermi-compost might be due to increased in fine organic particle which increased the total exchange sites of cations. Highest CEC was found in soil S_4 (32.37 Cmol (P^+) kg^{-1}), while the lowest in S_3(23.32Cmol (P^+) kg^{-1}) soil. "The organic amendments improve soil cation exchange capacity (CEC) through humus formation and increase concentrations of nutrients such as Ca and Mg as a result of decomposition"as it was founded by Jenkinson, 1990 and Johnston, 1997.Havlin *et al*. (1999) indicated that "the addition of different types of compostsuch as vermicomost and city compost into the soil increased CEC varying from 20% to 70% of initial values".The increase in CEC after the application of biological amendments has also been reported in previous researches bySeenivasan *et al*. 2015 and Nisha *et al*. 2018.

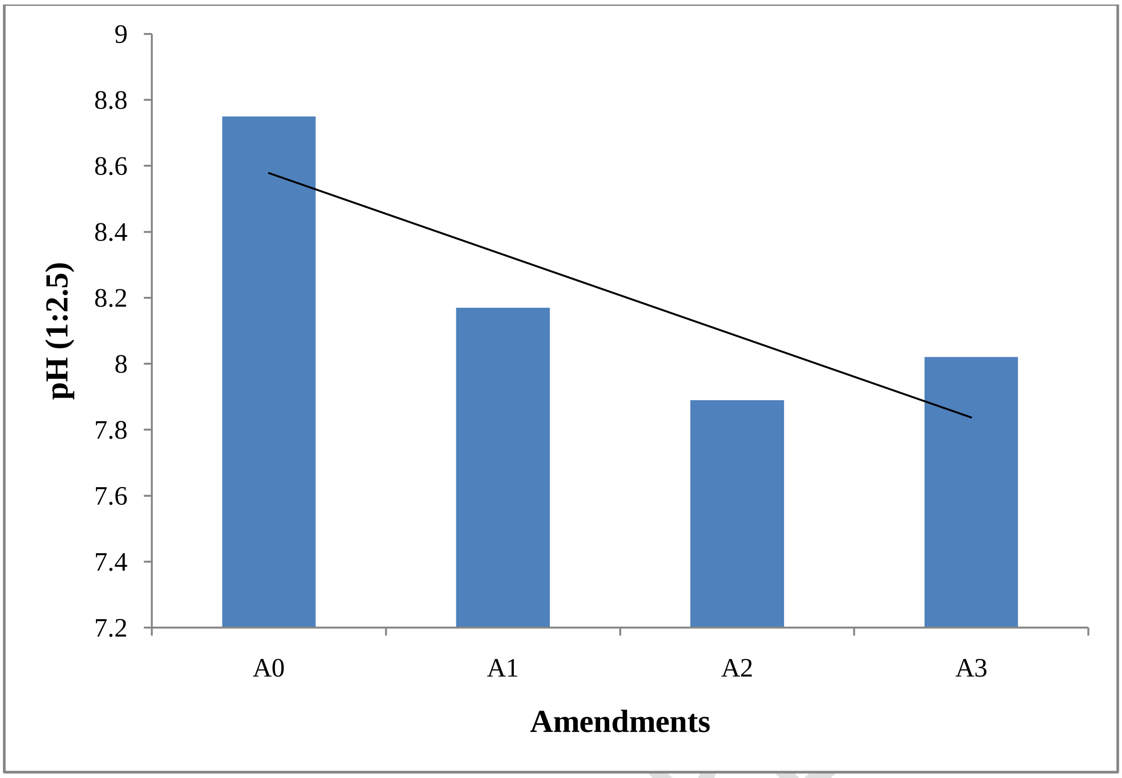

Fig. 1: Effect of amendments on pH of soils

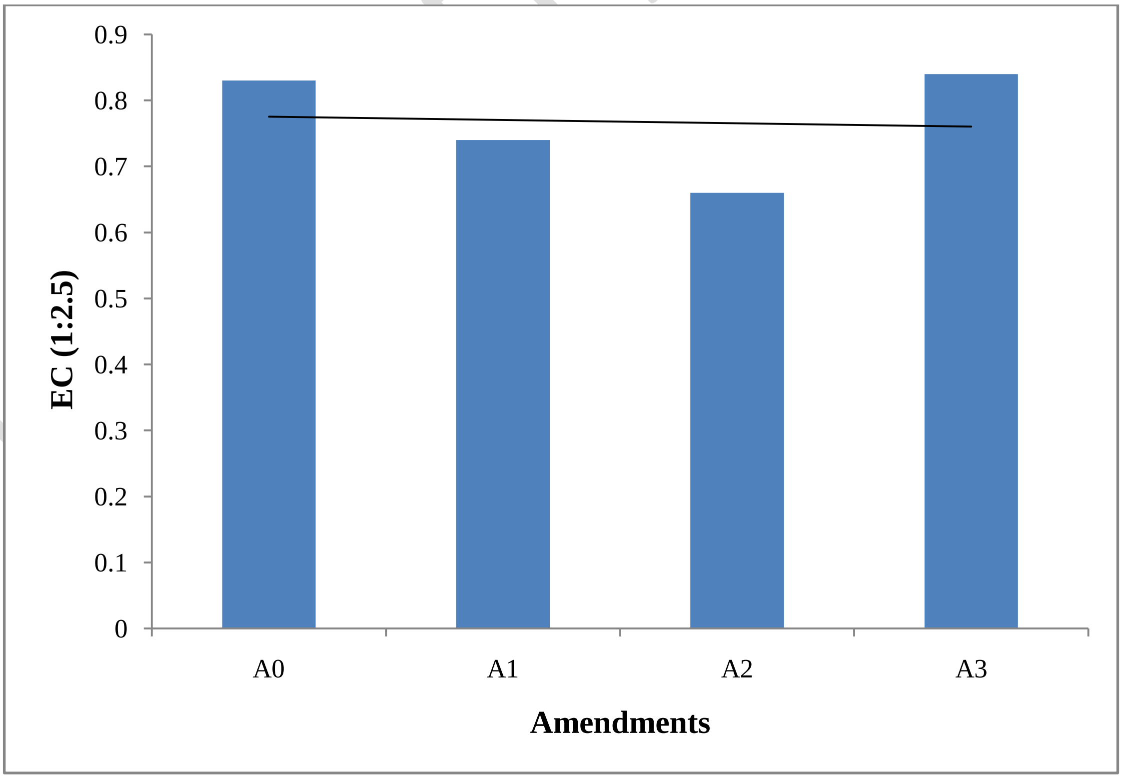

Fig. 2: Effect of amendments on electrical conductivity of soils

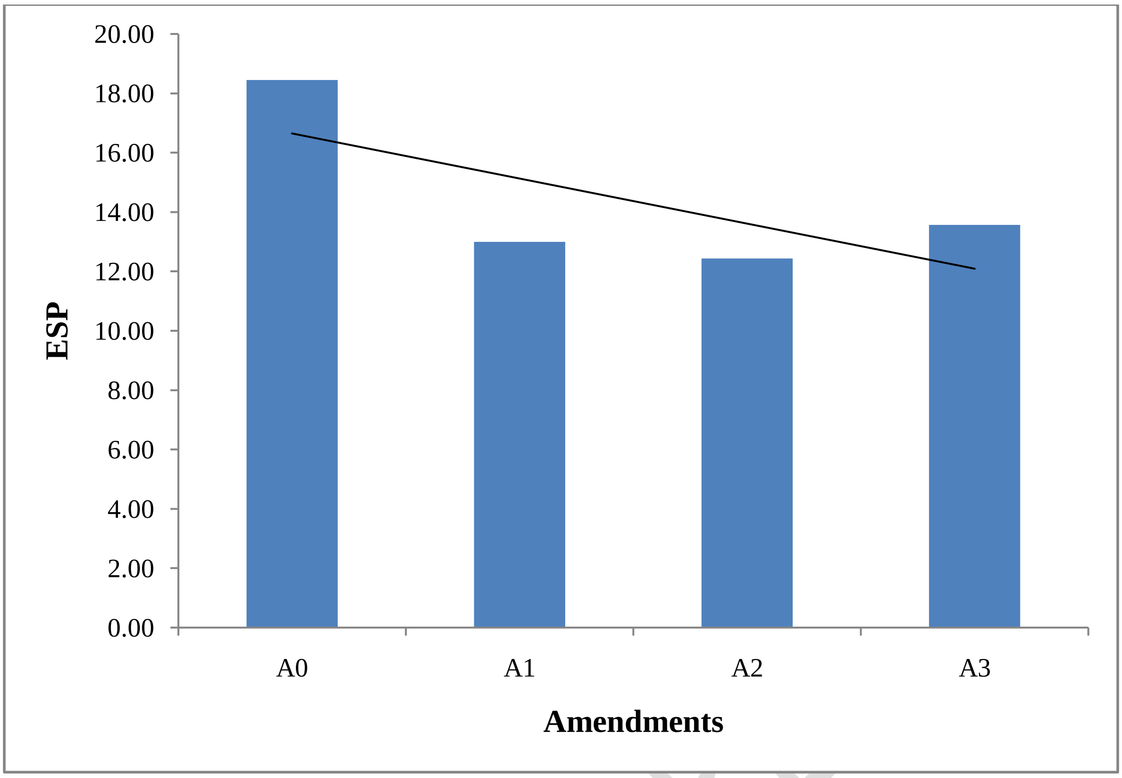

Fig. 3: Effect of amendments on ESP of soils

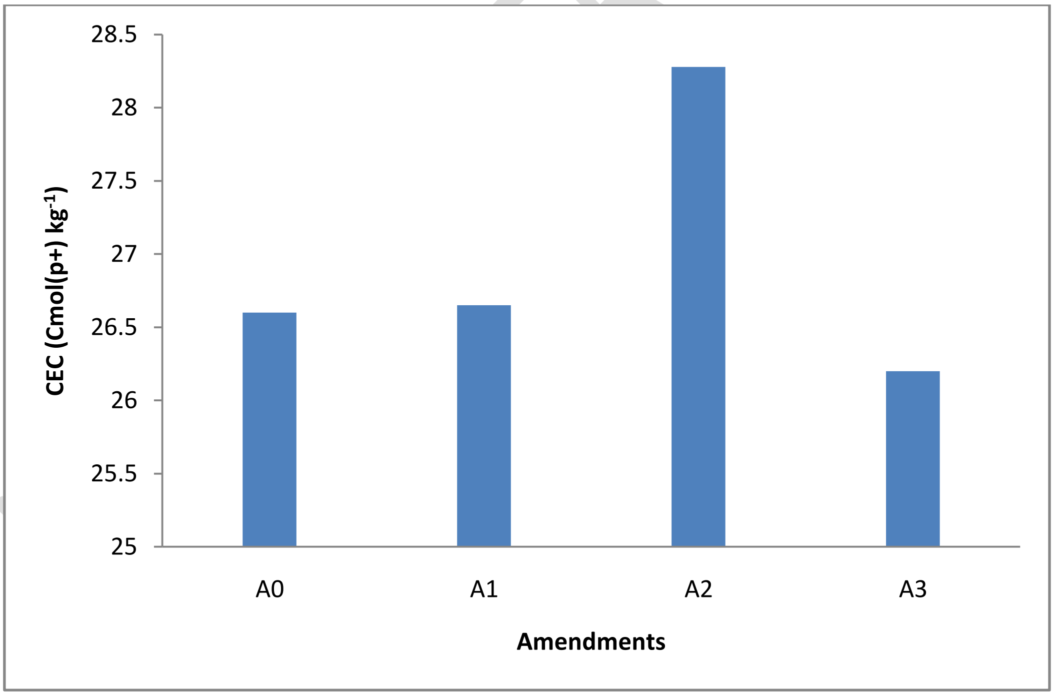

Fig. 4: Effect of amendments on CEC of soils

Table 3: Amelioration effect of amendments on chemical properties of soils.

Sr. No.	Treatments	$pH_{(1:2.5)}$	$EC_{(1:2.5)}$ (dSm^{-1})	ESP	CEC(Cmol (P^+) kg^{-1})
Types of Soils					
1	**S1**	8.16	0.64	12.90	23.22
2	**S2**	8.29	0.74	14.73	29.40
3	**S3**	8.31	0.88	14.69	23.32
4	**S4**	8.12	0.78	13.15	32.37
5	**S5**	8.39	0.92	16.48	24.41
6	**S6**	7.99	0.62	14.25	28.86
CD (P=0.05)		0.07	0.03	1.37	1.06
Types of amendments					
1	**A0 (control)**	8.75	0.83	18.45	26.60
2	**A1 (Gypsum @ 50% GR)**	8.17	0.74	13.00	26.65
3	**A2 (Vermi-compost @ 4.0 t ha^{-1})**	7.89	0.66	12.44	28.28
4	**A3 (sulphur @ 50 kg ha^{-1}).**	8.02	0.84	13.57	26.20
CD (P=0.05)		0.05	0.02	0.97	0.75
Interaction (S × A)		0.14	0.06	NS	NS
CV%		1.04	4.82	11.67	4.85

Table 4: Amelioration effect of amendments on nutrient status of soils.

Sr. No.	Treatments	OC %	Avail. P_2O_5 (kg ha^{-1})	Avail.K_2O (kg ha^{-1})	Avail. S (mg kg^{-1})	Avail. Fe (mg kg^{-1})	Avail. Zn (mg kg^{-1})	Avail. Mn (mg kg^{-1})	Avail. Cu (mg kg^{-1})
	Types of soil								
1	**S1**	0.41	26.53	126.9	12.54	9.73	0.95	8.03	2.17
2	**S2**	0.32	68.94	150.9	16.76	11.27	1.23	13.99	2.24
3	**S3**	0.67	63.90	326.6	14.07	8.80	1.09	10.50	1.35
4	**S4**	0.89	88.87	181.5	13.19	10.20	1.04	12.96	1.34
5	**S5**	0.63	51.51	197.1	9.34	13.85	0.57	9.98	2.73
6	**S6**	0.85	77.77	143.3	10.77	12.64	1.02	7.21	2.29
CD (P=0.05)		0.05	2.07	11.6	1.19	0.24	0.05	0.17	0.08
Types of amendments									
1	**A0 (control)**	0.54	60.87	172.2	9.22	10.38	0.88	9.81	1.96
2	**A1 (Gypsum @ 50% GR)**	0.62	62.93	183.2	13.77	11.29	1.00	10.65	2.02
3	**A2 (Vermi-compost @ 4.0 t ha^{-1})**	0.73	65.71	207.1	11.80	11.41	1.03	10.68	2.06
4	**A3 (sulphur@**	0.62	62.19	188.4	16.33	11.25	1.00	10.65	2.03

50 kg ha^{-1}).								
CD (P=0.05)	0.03	1.46	8.1	0.85	0.17	0.03	0.12	0.06
Interaction (S × A)	NS	NS	NS	NS	NS	NS	NS	NS
CV%	9.14	4.01	7.52	11.42	2.61	6.49	1.98	1.60

Effect on OC, P, K and S

The amendments showed significant effect on soil organic carbon content after harvest of wheat crop (Table 4). The results indicated that the highest OC was found due to vermi-compost application at 4.0 t ha^{-1} (0.73%) followed by sulphur at 50 kg ha^{-1} (0.62%) and gypsum at 50% GR (0.62%). A vermi-compostat 4.0 t ha^{-1} increased soil OC by 35.18% more over controltreatment. The organic matter addition through vermi-compost increased OC content in soil as similar finding with Tiwari *et al*., 2004.Singh *et al*., (2009) reported that addition of pressmud increased the soil organic carbon due to increase in yield and root biomass.The significant effect of vermi-compost and gypsum was observed over control on soil available P_2O_5 in soil after harvest of wheat. The significantly highest available P_2O_5 was recorded due to Vermi-compostat 4.0 t ha^{-1} (65.71 kg ha^{-1}) finfing is in line with Zakir *et al*., 2012,but the effect of sulphur and gypsum on available P_2O_5 was found at par. The available P_2O_5 was significantly influenced in soils S_2 to S_6 over soil S1 and the highest available P_2O_5 was recorded in soil S_4 (88.87 kg ha^{-1}). The interaction effect of different combination was found non- significant on available P_2O_5in soil. Itindicated that amendments showed significant effect on available K_2O of soil over control after harvest of wheat crop(Table 4). The highest available K_2O was found with vermi-compost application at 4.0 t ha^{-1} i.e., 207.1 kg ha^{-1}. The available K_2O was also increased under sulphur application next to vermi-compost, being at par with gypsum. The highest available K_2O was recorded in soil S3 (326.6 kg ha^{-1}) and the lowest in S (126.9 kg ha^{-1}). When organic materials are applied to soils it improve organic matter status, and also supply soils with nutrients including N, P and K (Tiwari*et al*., 2004; Zakir*et al*., 2012,:Xu *et al*., 2019). Reports also suggested that especially phosphorus in vermi-compost is released more gradually in available form in soil (Kale *et al*., 1987; Doube and Brown, 1998; Nethra*et al*., 1999; Lazcano*et al*., 2008). Azarmi*et al*. (2008) showed that addition of vermi-compostat 15 t ha^{-1} significantly ($P < 0.05$) increased contents of soil total organic carbon, total N, P, K, Ca, Zn and Mn substantially compared with control plots. The addition of vermi-compost in soil resulted in decrease of soil pH. The physical properties such as bulk density and total porosity in soil amended with vermi-compost were improved. The results of this experiment revealed that addition of vermi-compost had significant ($P < 0.05$) positive effects on the soil chemical and physical properties.

The data presented in Table 4, indicated that amendments significantly increased the available S content of soil. The application of sulphur (50 kg ha^{-1}) showed the highest available S (16.33 mg kg^{-1}), followed by gypsum at 50% GR (13.77) and vermi-compost at 4.0 t ha^{-1} (11.80 mg kg^{-1}). The available S was recorded the highest in soil S2 (16.76 mg kg^{-1}), while the lowest in S5 (9.34 mg kg^{-1}). Application of sulphur increased the available S might be due to 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 (Singh *et al*., 1981; Ghafoor and Muhammad, 1981).

Effect on micronutrients:

The amendments showed significant effect on DTPA extractable micronutrients (Fe, Mn, Zn, Cu) after harvest of wheat in sodic soils. The application of vermi-compost (4.0 t ha^{-1}) recorded numerically high available Fe, Mn, Zn and Cu i.e., 11.41, 10.68, 1.03 and 2.06 mg kg^{-1}respectively, being at par with gypsum (50% GR) and sulphur (50 kg ha^{-1}). Which supported by decrease in soil pH. Irrespective of amendments, soils S5, S4, S2 and S5 recorded the highest available Fe, Mn, Zn and Cu, while the lowest in S3, S6, S5 and S4, respectively. In study, the effect of vermi-compost found better over other amendments in increasing micronutrient availability of soil. This might be due to the micro-organisms in the vermi-products play a significant role in altering the soil micronutrient content as said by Azarmi *et al*., 2008. The microbial activity induced by the bio-fertilizers increase the soil microorganism activity by availing additional substances that are not found in chemical fertilizers. Azarmi*et al*. (2008) showed that addition of vermi-compost application at 15 t ha^{-1} significantly ($P < 0.05$) increased contents of soil total organic carbon, total N, P, K, Ca, Zn and Mn substantially compared with control plots.

Conclusion:

The result of this experiment showed that various amendments used in this study, decreased the pH, EC and ESP of various soilsas compared to theire original values. The order effectiveness in decreasing pH irrespective of soil types from 8.75 to 7.89 by remained as: vermi-compost> sulphur > gypsum. All the amendments showed significant effect on soil OC, available P_2O_5, K_2O, SO_4-S, DTPA extractable Fe, Mn, Zn, Cu after harvest of wheat and the highest OC (0.73%), available P_2O_5 (65.71 kg ha^{-1}), available K_2O (207.1 kg ha^{-1})

was recorded when vermi-compost applied at 4.0 t ha^{-1} followed by sulphur at 50 kg ha^{-1} and gypsum at 50% GR but the highest available S (16.33 mg kg^{-1}) was recorded due to sulphur application @ 50 kg ha^{-1} followed by gypsum and vermi-compost.Therefore from the result of this experiment, it could be recommended that in the given types of soil vermi-compost at the rate of 4.0 t ha^{-1}found best as a amendment.

Competing interest:Authors does not have conflict of interest with anyone.

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 Premlata Meena 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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