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Studies on the effect of gypsum on structural indices of soil

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Abstract

A field investigation relating to Studies on the Effect of Gypsum on Structural Indices of Soil. was conducted at Agronomy farm, College of Agriculture, Nagpur. The field experiment was laid out in randomized block design (RBD) with a seven treatments replicated thrice. Treatments consisted of 1, 1.5, 2, 2.5, 3, 5 t gypsum per hectare and a control. The samples were taken from (0-30 cm) and (30-60 cm) depth for conducting study. The surface soil of experimental site was slightly alkaline in reaction clayey in texture, medium in organic carbon (6.21 kg^{-1}), low in available nitrogen (206.98 kg), medium in phosphorus (19.23 kg ha^{-1}), high in potassium (503.00 kg ha^{-1}) poor in hydraulic conductivity (1.06 cm ha^{-1}). The CEC of surface and subsurface soil was 52.16 and 53.70 {cmol (p^+) kg^{-1}} and Ca/Mg ratio of was 1.30 and 1.21 respectively. Increasing level of gypsum improves physical and chemical properties of soil and higher improvement was found with higher doses of gypsum. However T_3 (1.5 t gypsum ha^{-1}) is sufficient to maintain enough electrolyte concentration to increase HC. Application of 5 t gypsum ha^{-1} improves Mean weight diameter, Aggregate stability and Water stable aggregates. Application of gypsum increases exchangeable Ca^{2+} and increases Ca/Mg ratio of soil and reduces exchangeable Na^+, ESP soil, which have favourable impact on hydraulic conductivity. Increasing level to gypsum also increased the availability of N at higher level.

Keywords: Gypsum, structural indices, soil

1. Introduction

The unique properties special to vertisols are high clay content, volume changes with moisture, cracks that split and merge periodically and evidence of soil movement in the form of slicken slides and of wedge shaped structural aggregates that are tilted with an angle from the horizon. The shrink-swell phenomenon which is responsible for the genesis and behavior of vertisols is a complex, dynamic and yet incompletely understood set of processes. (Gokhan and Aksoy, 2007) [7].

The poor structural stability of Vertisols particularly during the monsoon season render the agricultural activity difficult, the low saturated hydraulic conductivity causes water logging. As a result vast land remain vacant particularly during monsoon season (Sen, 2003) [14].

Increases in ESP and EMP with depth have adversely affected the hydraulic and other properties important for crop growth. Saturation of these soils, not only with Na^+ ions but also with Mg^{2+} ions leads to greater dispersion of clay, which is the opposite effect from that saturation with Ca^{2+} ions, which leads to the blocking of small pores in the soil. In other words, Mg^{2+} ions are less efficient than Ca^{2+} ions in flocculating soil colloids. However due to high evaporative demand for soil water in the semi-arid climatic condition, maintenance of a proper Ca/Mg ratio in the soil solution becomes difficult because Ca^{2+} ion get precipitate as $CaCO_3$ result in depletion of Ca^{2+} ions from the soil solution (Balpande *et al.*,1996) [2]. The Vertisols have enough $CaCO_3$ but the soluble calcium concentration in the saturation extract of the many Vertisols were is 0.6 to 3.6 mmol L^{-1} and this amount is not enough to inhibit the swelling of smectite by contracting the diffuse double layer. This indicates the inertness of calcite to inhibit the swelling of smectite (Balpande *et al.*, 1997) [3].

Under rainfed condition yield of crop depends primarily on the amount of rain stored in soil profile and extend to which this water is released during crop growth. More over both retention and release of soil water are governed by the nature and content of clay minerals, and also by the nature of exchangeable cations.

The exchangeable polyvalent cations (e.g. Ca) near clay surfaces reduces the thickness of the diffuse double layer. The reduction in repulsive forces acting between clay particles (Emerson 1983) [6] helps for the flocculation of clays and increased resistance to dispersion (the Schultze- Hardy Rule). Calcium rather than Mg or K on the exchange complex was associated with stable aggregates in Australian subsoils (Emerson and Bakker 1973) [5]. Pojasok and Kay (1990) found aggregate stability to increase with Ca concentrations in soil solution.

In the view of above consideration, field experiment entitled Studies on the Effect of Gypsum on Structural Indices of Soil was conducted with following objectives, Effect of Gypsum on Structural Indices of Soil.

2. Materials and Methods

The field investigation in relation to Studies on the Effect of Gypsum on Structural Indices of Soil was conducted during Kharif and *Rabi* season at Agronomy Farm, College of Agriculture, Nagpur. The details of material used and methods adopted during the period of investigation are given in this chapter under appropriate heads.

2.1 Experimental site

The field experiment entitled "Studies on the Effect of Gypsum on Structural Indices of Soil**.**, was carried out at Extra Assistant Director (EAD) farm, College of Agriculture Nagpur. The field selected for conducting experiment was fairly uniform and leveled.

2.2 Soil of experimental area.

The soil under the experimental study was fine montmorillonite of Typic Haplustert, In order to study the physical and chemical properties soil samples were taken from 0-30 and 30-60 cm depth with the help of screw auger from randomly selected spots over the experimental field before sowing. The soil of the experimental field was clay in texture. The result of the chemical analysis data indicate that soil was low in available nitrogen, medium in available phosphorus, very high in available potassium, medium in organic carbon, low in available sulphur soil pH was 8.10 and electrical conductivity recorded 0.20 dS m^{-1}

2.3 Climate and Weather conditions

Nagpur is situated at 21º 10' North latitude and 19º 19' East latitude at elevation of 321.26 meter above sea level and lies under sub-tropical zone. Nagpur is characterized by hot and dry summer and fairly cold winter. This area shows wide diurnal fluctuation in temperature. The maximum and minimum temperature ranged from 43.3 to 8.5ºC respectively. Whereas relative humidity varied from 13% to 90%. During the crop growth period mean annual precipitation was about 928.8 mm and major amount of it is received from June to December within 46 rainy days.

2.4 Experimental details

2.4.1 Design of experiment and treatments

The experiment was laid out in randomized block design (RBD) with seven treatments each replicated thrice, the detail of treatment are presented below.

1	**Location**	:	**Agronomy Farm, College of Agriculture, Nagpur.**
2	Name of the crop (Kharif)	:	Soybean (JS-335)
	(Rabi)	:	Chickpea (JAKI -9218)
3	Design of experiment	:	Randomized Block Design (RBD)
4	No. of Treatments	:	7
5	No of Replication	:	3
6	Total no. of plots	:	21
7	Plot size	:	Gross 6 x 5.4 m
		:	Net 4x3.6 m
8	Spacing (soybean)	:	30 x 5 cm^2
	(Chickpea)	:	30 x 10 cm^2
9	Fertilizer dose (soybean)	:	30:75:00 NPK kg ha^{-1}
	(Chickpea)	:	25:50:00 NPK kg ha^{-1}
10	Seed rate (soybean)	:	80 kg ha^{-1}
	(Chickpea)	:	100 kg ha^{-1}
11	Method of sowing (soybean)	:	Drilling
	(Chickpea)	:	Drilling

2.4.2 Treatment details

T_1: Control (no Gypsum)
T_2: 1.0 t ha^{-1} gypsum
T_3: 1.5 t ha^{-1} gypsum
T_4: 2.0 t ha^{-1} gypsum
T_5: 2.5 t ha^{-1} gypsum
T_6: 3.0 t ha^{-1} gypsum
T_7: 5.0 t ha^{-1} gypsum

2.4.3 Fertilizer application

The fertilizer application was done as per recommended doses (experimental details) for both the crop. Nitrogen and phosphorus were applied through Urea and SSP respectively, fertilizers doses were applied to different plot at the time of sowing.

3. Methodology for gypsum application

Gypsum in powder form was applied to different plots as per treatments before sowing of soybean crop. The proper care was taken for equal mixing of gypsum in surface soil and for that after application of gypsum to soil it was equalized by turning surface soil.

3.1 Soil sampling and processing

Initial treatment wise soil samples from (0-30 cm) and (30-60 cm) depth after harvest of soybean were collected. The soil samples were dried in shade and gently grind with wooden pestle and mortar and sieved through 2mm sieve. These samples were stored in polythene bags and were subsequently analysed for various properties.

3.2 Collection of soil sample for soil moisture study

The treatment wise soil samples were collected with the help of screw auger from (0-30 cm) and (30-60 cm) depth between the two rows at an interval of 15. These samples were immediately put in pre weighed aluminum boxes for determination of moisture content by gravimetric method.

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4. Soil analysis
4.1 Physical properties
Large clods were broken by hand into smaller segments along natural cleavage prior to air drying. The air drying soil was sieved to obtain aggregates that passed through 8 mm and retained on 5mm sieved (5-8 mm size fraction). Therefore, aggregate size range of 5-8mm reflects the whole soil fraction in terms of soil matrix because 100% of the soil was in this ranged. The aggregates were sieved using the wet sieving technique (Yoder 1936; Kemper And Rosenau 1986S). Hundred grams of soil aggregates (5-8mm diameter) were placed on a nest of sieves (5, 2, 1, 0.5, 0.25, 0.10 and 0.053mm), sieved for 30 minutes at 30 strokes per minutes. After wet sieving, aggregates from each sieve were transferred to a set of pre- weighed beakers, oven dried at 60ºC until water evaporated, and weighed.
The total sand content of each aggregate size fraction was determined by weighing the material that was retained on the sieve with a 0.053mm screen upon dispersal of the aggregates with 5 gram per liter of sodium hexameter phosphate solution.

a) Mean weight diameter
The mean weight diameter was calculated as an index of aggregation (Van Bavel 1949, Youker and McGuiness 1956).

Mean weight diameter $=\sum$ Xi Wi

Where
Xi = Mean weight diameter
i = 0.0765, 0.175, 0.375, 0.75, 1.5, 3.5 mm
Wi= the proportion of total sample weight occurring in the fraction.

b) Percent aggregate stability
The percent aggregate stability was determined as the procedure outlined by Gupta and Dakshinamurthy (1980).
Percent aggregate stability = [(weight soil particles > 0.25mm – weight of sand > 0.25mm) / (oven dry weight of soil – weight of sand > 0.25mm)]×100

c) Water stable aggregates
Water stable aggregates were determined by summation of the material retained on all sieves and computing aggregation as percent of original universal soil amount (Yodder 1936).
Water stable aggregates (%) = (weight of aggregates in each group / total weight of soil) ×100

4.2 Physical analysis
a. Soil moisture content: The soil moisture was determined by thermo gravimetric method. The moisture percent was calculated by using following formula as described by Richard, 1954.

$$\text{Gravimetric moisture content (\%)} = \frac{w_1 - w_2}{w_2} \; x100$$

W_1: Initial weight of soil
W_2: Oven dry weight of soil

b. Bulk density
Soil core were collected with the help of core sampler, oven dry weight of each core was taken and bulk density was calculated using oven dry weight and volume of core as described by Black, (1966).

c. Saturated hydraulic conductivity
Processed soil sample dump into perforated soil container in one motion, cylinder containing soil was dropped 20 times through distance 2.5 cm and allow to saturated for 24 hour through bottom with the distilled water, then constant water head was maintain and HC was calculated from the volume of water collected in unit time as described by Richards (1954).

4.3 Chemical analysis
a. Soil reaction (pH)
It was determined by glass electrode after equilibrating soil with distilled water for 30 minutes in the ratio of 1:2.5 soil water suspension as per described by Piper, (1966) [11].

b. Electrical conductivity
It was determined with conductivity meter using 1:2.5 soil water suspensions after allowing sufficient time to settle soil particles of solution to get clear supernant as described by Piper, (1966) [11].

c. Cation exchange capacity
Cation exchange capacity was estimated by saturation of 2 mm soil with 1 N sodium acetate(pH 8.2) and extract with 1 N ammonium acetate (pH 7.0). Then removing the excess sodium acetate by centrifuge with 95 percent ethanol till supernant get and EC of 0.44 to 0.45 dSm^{-1}. The adsorb sodium was then replace by ammonium acetate solution having neutral pH (7.0) a sodium concentration in leachate was determined by flame photometer as suggested by Jackson (1967) [8].

d. Exchangeable Ca^{2+} and Mg^{2+}
The exchangeable calcium and magnesium were determined by leaching sample with 1N ammonium (pH 8.2) solution and titrating the lechate with standard EDTA solution as method described by Richard, (1954).

e. Exchangeable Na^{+} and K^{+}
Exchangeable sodium and potassium were determined by leaching with 1 N ammonium acetate (pH 1.8) solution Na^{+} and K^{+} from leachate were estimated using flame photometer (Piper, 1966) [11].

f. Free calcium carbonate
Calcium carbonate was determined by rapid titration procedure. The soil was treated with standard hydrochloric acid to neutralize all carbonate present in soil. The unreacted hydrochloric acid was back titrated with standard sodium hydroxide using phenolphthalein indicator as described by piper, (1966) [11].

g. Organic carbon
Organic carbon was estimated by Walkley and Black's wet oxidation method. The organic carbon content in soil was oxidized by chromic acid by using heat of dilution of sulphuric acid. The unreacted chromic acid was back titrated with standard ferrous ammonium sulphate as described by piper, (1966) [11].

h. Available Nitrogen

It was determined by alkaline permanganate method as described by Subbaiah and Asija (1956) [15]. The organic matter in soil is oxidized by $KMnO_4$ in the presence of NaOH. The ammonia released during oxidation is absorbed in boric acid to convert the ammonia to ammonium borate. Ammonium borate formed is titrated with standard sulphuric acid. From H_2SO_4 required for reaction with ammonium borate the nitrogen calculated.

i. Available Phosphorus

The soil was extracted with Olsen's reagent 0.5 m $NaHCO_3$ of pH 8.5 and from the extract available P was estimated calorimetrically as per Jackson, (1967) [8].

j. Available Potassium

The available K was estimated by extracting the soil with 1 N NH_4OAC (pH 7.0) and concentration of K in the extract was measured using flame photometer Jackson (1967) [8].

k. Available Sulphur

Available sulphur was estimated by Morgan's extract with turbidity method using colorimeter as described by Chopra and Kanwar, (1976).

5. Result and Discussion

The present investigation entitled Studies on the Effect of Gypsum on Structural Indices of Soil were carried out by conducting a field trial of soybean and chickpea. The results obtained and inferences drawn were discussed under following heads.

i. Physical and chemical properties of soil after harvest of crop
ii. Ion exchange analysis of soil.
iii. Nutrient status of soil after harvest of the crop.

5.1 Physico-chemical properties of soil after harvest of crop.

5.1.1 Physical properties of soil after harvest of crop.

The data pertaining to physical properties of soil i.e. bulk density, hydraulic conductivity and aggregate stability are presented in table 1. Although the data were non-significant in some parameters, there was a definite trend obtained with increasing level of gypsum, which indicates positive effect of calcium in improvement of physical condition.

5.1.2 Bulk density

Enhancement in bulk density of soil with increasing depth may be ascribed to increasing compactness of soil at lower depth, and surface application of gypsum found to decrease bulk density of soil over control. In surface soil (0-30 cm) decreased was found under treatment T_7 and T_6 1.27 Mg m^{-1} over control (no gypsum) 1.32 Mg m^{-3}. In sub soil (30-60 cm) it varied from 1.36 to 1.42 Mg m^{-3} under various treatments. The suppression of B.D. may be due to good aggregation of soil by exchangeable Ca^{2+} and low exchangeable Na^{+}, which may be due to application of gypsum. Verma and Gupta (1985) [17] observed that bulk density of Vertisols decreased with reduction in sodium content and improvement in calcium content on the exchange complex. The results are in agreement with Bhattacharyya *et al.* (2001) [4] and Mathan (2000) [9].

5.1.3 Hydraulic conductivity

Gypsum application significantly improved the hydraulic conductivity of surface soil, however increased in H.C. of sub surface soil was non-significant. The highest improvement in surface hydraulic conductivity (1.23 cm hr^{-1}) was under treatment T_7 (5 t gypsum ha^{-1}) and found significantly superior over T_1 (1.08 cm hr^{-1}), T_2 (1.10 cm hr^{-1}), and at par with T_6 treatment (1.21 cm hr^{-1}) which received 3 t gypsum per hectare. Also the treatment T_5 (2.5 t gypsum ha^{-1}) found significantly superior over treatment T_1, T_2 and T_3 and at par with T_4 (2 t gypsum ha^{-1}). The lowest value of HC was recorded under control (1.08 cm hr^{-1}). While in sub-soil increased in value of H.C. was non significant and highest values was registered under treatment T_7 (1.07 cm hr^{-1}) followed by T_6 (1.05 cm hr^{-1}) and minimum values was recorded under control and treatment T_2 (0.92 cm hr^{-1}). The low H.C. in sub-soil is due to its slightly higher clay with lower Ca/Mg ratio causes more swelling and dispersion (Balpande *et.al.*, 1996) [2].

Table 1: Effect of gypsum on physical properties of soil after harvest of crop

	Bulk density (Mg m^{-3})		Hydra. Cond. (cm hr^{-1})		MWD (mm)		Aggregate Stability (%)		Water stable aggregates (%)	
Depth, cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
Treat.										
T_1	1.32	1.40	1.08	0.92	0.696	0.685	63.3	63.17	80.1	79.70
T_2	1.31	1.38	1.10	0.92	0.704	0.697	68.5	63.50	82.3	80.03
T_3	1.30	1.37	1.15	0.93	0.705	0.702	68.5	66.07	81.5	80.00
T_4	1.28	1.35	1.18	0.96	0.708	0.688	69.9	67.00	81.2	81.37
T_5	1.28	1.38	1.20	1.01	0.711	0.688	70.3	66.90	82.9	81.97
T_6	1.27	1.36	1.21	1.04	0.712	0.698	70.3	67.67	83.6	81.20
T_7	1.27	1.34	1.23	1.07	0.715	0.701	72.1	66.37	83.8	82.37
SE (m)	0.01	0.01	0.07	0.038	0.006	0.005	0.87	1.04	0.96	0.67
C.D.@ 5%	-	-	0.023	-	0.018	0.015	2.6	-	2.9	-

The improvement in H.C. of soil in surface soil after application of gypsum is mainly attributed to increase in electrolyte concentration, decline in water dispersible clay %, increased in Ca/Mg ratio that might have favourable impact on structural stabilization. and Sagare *et al.* (2001) [12] found similar result while working on the Vertisols.

5.1.4 Mean Weight Diameter

The mean weight diameter ranged from 0.696 mm to 0.715 mm at surface soil. The highest value was recorded in T_7 (0.715 mm) which is superior over T_1 (0.696 mm) and at par with rest of the gypsum treatments. Gypsum application also influences MWD in sub soil region. The highest value recorded was 0.702 in T_3 which is superior over T_1 and at par with rest of the treatments. Increase in mean weight diameter in gypsum applied treatments could mainly be due to improved soil aggregation.

5.1.5. Aggregate Stability

Increasing levels of gypsum showed higher aggregate stability of surface soil. The highest value recorded was 72.1% in T_7 which is superior over T_1, T_2 and T_3 and was found at par with T_4, T_5 and T_6. However, sub soil showed slight improvement in aggregate stability although the data is non-significant.

The beneficial effect of gypsum in increasing aggregate stability may be due to calcium present in gypsum which act as binding agent to clay particles. (Emersion, 1983).

5.1.6. Water Stable Aggregate

A significant increase in percent water stable aggregates was observed in surface soil. It ranged from 80.1 to 83.8 %. The highest value was recorded in T_7 (83.8%) which was superior over control and at par with rest of the treatments which might be due to improvement in soil structure. While subsurface soil showed non-significant effect.

Selvi *et.al.*, (2005) [13] observed an increase in the percentage of water stable aggregates of size greater than 0.25 mm due to contineous application of FYM with fertilizer and lime in vertic haplustepts of Tamil Nadu.

5.1.7. Chemical properties of soil after harvest of the crop.

5.1.7.1 Soil reaction (pH).

The pH of the soil was significantly decreased due to the increasing level of gypsum, over no gypsum, in surface soil and in sub-soil increase was not significant. The maximum decrease in pH was found with treatment T_7 (5t gypsum ha^{-1}). The gypsum application 1.0 t ha^{-1} (T_2) also observed significantly decreasing pH of surface soil. In sub soil pH ranged between 8.15 to 8.06.The decrease in pH was found mainly due to replacement of Na^+ with Ca^{2+} added through gypsum. Decrease in pH due to application of gypsum in vertisols was very well noticed by Sagare *et al.* (2001) [12].

5.1.7.2 EC, Electrical Conductivity

The EC of soil in surface layer was observed significantly influenced by gypsum treatment Highest EC (0.41 d Sm^{-1}) was found with treatment T_7 (5 t ha^{-1} gypsum). While in sub soil EC was found to increased non significantly and ranged between 0.24 to 0.30 dSm^{-1}. The data also reveals that with increasing level of gypsum increases the EC of soil by increasing total soluble salt content. However, EC remains under harmful level of < 1.0 dSm^{-1}.

5.1.7.3 Organic carbon

The organic carbon status of surface soil under various treatment ranged between 6.22 to 6.30 g kg^{-1} while in sub soil it ranged between 4.63 to 4.87 g kg^{-1} Organic carbon status of surface soil found more as compare to sub-soil because of addition of organic matter through manuring and crop residues incorporation. The effect of gypsum application on organic carbon status was non-significant.

5.1.7.4 Calcium carbonate

The $CaCO_3$ content found higher in sub-soil and ranged between 5.46to 6.08 percent compared to surface soil which ranged between 4.64 to 4.93 percent. The higher calcium carbonate content might be due to leaching of bicarbonate in these soil from upper layer during the rainy season and their subsequent precipitation as carbonate in lower layer during dry periods (Balpande *et al.*, 1996) [2]. The $CaCO_3$ content in these soils failed to maintain sufficient Ca^{2+} ions in soil solution due to low solubility, less moisture content and poor partial pressure of CO_2.

Table 2: Effect of gypsum of chemical properties of soil after harvest of the crop

	pH		EC (dSm^{-1})		OC (g kg^{-1})		$CaCO_3$ (%)	
Depth cm	**0-30**	**30-60**	**0-30**	**30-60**	**0-30**	**30-60**	**0-30**	**30-60**
Treatments								
T_1	8.07	8.15	0.19	0.24	6.22	4.87	4.93	6.08
T_2	8.04	8.12	0.23	0.25	6.23	4.83	4.87	5.71
T_3	8.03	8.13	0.26	0.26	6.24	4.79	4.85	5.46
T_4	7.95	8.09	0.28	0.28	6.25	4.77	4.64	5.70
T_5	7.90	8.08	0.32	0.29	6.30	4.70	4.73	5.62
T_6	7.87	8.08	0.35	0.30	6.28	4.66	4.76	5.61
T_7	7.84	8.06	0.41	0.28	6.30	4.63	4.71	5.90
SE (m)	0.014	0.05	0.01	0.01	0.01	0.05	0.06	0.18
C.D. at 5%	0.042	-	0.03	-	-	-	-	-

5.2 Ion exchange analysis data of soil after harvest of crop.

5.2.1 Exchangeable captions

Data related to exchangeable cations presented in table 10. It showed that increasing level of gypsum significantly increases the exchangeable Ca^{2+} in surface soil, while in sub-soil increase was non-significant. The maximum improvement {32.58 cmol (p^+) kg^{-1}} in exchangeable calcium was found with treatment T_7 (5 t gypsum ha^{-1}), which is at par with T_6 {31.78 cmol (p^+) kg^{-1}} and superior over rest of the treatments. The minimum exchangeable calcium found in control {27.98 cmol (p^+) kg^{-1}}. The increasing dose of gypsum was found to significantly decrease the exchangeable magnesium of surface soil while in sub soil effect was non-significant. The significantly maximum decrease magnesium {17.57 cmol (p^+) kg^{-1}} was found with T_7 (5 t gypsum ha^{-1}) over control {21.10 cmol (p^+) kg^{-1}}. The decrease in exchangeable Mg^{2+} is due to replacement with Ca^{2+} supplied through gypsum. This also found by Armstrong and Tanton (1992) [1]. The increasing level of gypsum significantly decrease exchangeable Na^+ of surface soil while effect of was non-significant on sub-soil. Decrease in exchangeable Na^+ is mainly due to replacement with Ca^{2+} and maximum decrease {0.66 cmol (p^+) kg^{-1}} was found with T_7, which is at par with T_6 {0.78 cmol (p^+) kg^{-1}] and T_5 {0.99 cmol (p^+) kg^{-1}} and significantly superior over rest of the treatments. The maximum exchangeable sodium in surface soil was found in control {1.49 cmol (p^+) kg^{-1}}. In sub-soil exchangeable sodium varied over range 1.61 to 1.52 {cmol (p^+) kg^{-1}}. Decrease in exchangeable sodium content with application of gypsum was also noticed by Armstrong and Tanton (1992) [1]. Levels of gypsum have not showed any significant effect on exchangeable K^+ in surface and sub-soil and ranged between 0.44 to 0.48 {cmol (p^+) kg^{-1}} and 0.43 to 0.48 {cmol (p^+) kg^{-1}} respectively.

5.2.2 Cation exchange capacity

Cation exchange capacity is function of clay per percentage in soil. However increasing level of gypsum did not show any effect on cation exchange of capacity of soil. In surface soil it ranged between 52.20 {cmol (p^+) kg^{-1}} to 52.38 {cmol (p^+) kg^{-1}} and in sub-soil it ranged over 53.23 to 53.69 {cmol (p^+) kg^{-1}}.In sub-soil CEC found more due to higher percentage of clay in sub-soil.

5.2.3 Exchangeable sodium percentage and Ca/Mg ratio

Increasing level of gypsum significantly reduce the ESP of surface soil (table 8) and maximum reduction in ESP (1.26) was found with treatment T_7 which was found at par with T_6 (1.49). In control plot ESP (2.85) was found due to sodium on exchange complex. In sub soil reduction ESP was non significant and ranged over 2.85 to 3.01. Reduction in ESP with application of gypsum was found high due to reduction of exchangeable sodium from exchange complex. It was also observed by Sagare *et al.* (2001) [12]. The reduction in ESP with gypsum treatment was likely due to direct supply of soluble Ca^{2+} for replacing exchangeable Na^+ (Milapchand *et al.,* 1977). The 2.82 to 3.01 ESP in sub soil indicate the initiation of a sodification process in these soils (Balpande *et al.*, 1996) [2].

The Ca/Mg ration of surface soil significantly increased with increasing level of gypsum (table 9) and maximum ratio 1.85 was found with treatment T_7 over control (1.32). The increasing Ca/Mg ratio might be due to the replacement of Na^+ and Mg^{2+} by soluble Ca^{2+} supplied through gypsum (Amstrong and Tanton, 1992) [1]. The effect of addition of gypsum in sub soil was observed non-significant.

5.3 Nutrient status of soil after harvest of the crop

Available N, P, K and S of soil after harvest of soil are present in table 11. Data showed data available N, P and K content of soil was not significantly influenced by increasing level of gypsum on surface soil and it ranged between 220.78 to 232.82 kg ha^{-1}, 23.24 to 24.55 kg ha^{-1} and 558.36 to 570.98 kg ha^{-1} respectively. In sub-soil available N and P content was found less as compared to surface soil and ranged between 199.29 to 203.16 kg ha^{-1} and 19.65 to 20.70 kg ha^{-1} respectively. Available K in sub-surface soil was found in the range of 536.13 to 543.98 kg ha^{-1}, and there were not much difference found in surface and sub-soil K status.

Increasing level of gypsum significantly increase available S of surface soil (table 10) and significantly highest available S 41.58 kg ha^{-1} was found with treatment T_7 which were at par with T_6 (38.76 kg ha^{-1}) minimum available S was found under control 16.19 kg ha^{-1}. Available S of the sub soil non significantly influenced by increasing dose of gypsum and ranged between 18.81 to 21.46 kg ha^{-1}. Increasing sulphur status of Vertisols due application of gypsum was observed by Saha *et al*. (2001) [16].

Table 3: Effect of gypsum on Ion exchange properties of soil.

Treatments.	Depth (cm)	Exchangeable cations				Sum of cations	CEC	Base saturation	ESP	Ca/Mg ratio
		Ca^{2+}	Mg^{2+}	kg^{-1}}Na^+	K^+					
		{cmol (p^+) kg^{-1}}						(%)	(%)	
T_1	0-30	27.98	21.10	1.49	0.44	51.01	52.36	97.42	2.85	1.32
	30-60	27.07	21.57	1.55	0.43	50.62	53.31	94.95	2.91	1.25
T_2	0-30	28.44	20.54	1.38	0.45	50.81	52.22	97.30	2.64	1.38
	30-60	26.94	21.27	1.57	0.43	50.21	53.46	93.92	2.94	1.26
T_3	0-30	29.3	19.99	1.28	0.46	51.03	52.28	97.61	2.45	1.46
	30-60	27.30	21.67	1.55	0.46	50.98	53.69	94.95	2.89	1.25
T_4	0-30	30.15	19.27	1.19	0.47	51.08	52.2	97.85	2.28	1.56
	30-60	27.86	21.16	1.52	0.48	51.02	53.37	95.60	2.85	1.31
T_5	0-30	31.04	18.45	0.99	0.49	50.97	52.22	97.61	1.90	1.68
	30-60	28.1	21.30	1.61	0.48	51.49	53.44	96.35	3.01	1.32
T_6	0-30	31.78	18.24	0.78	0.48	51.28	52.38	97.90	1.49	1.74
	30-60	28.65	21.46	1.57	0.46	52.14	53.23	97.95	2.95	1.33
T_7	0-30	32.58	17.57	0.66	0.48	51.29	52.25	98.16	1.26	1.85
	30-60	27.64	20.82	1.56	0.48	50.5	53.25	94.84	2.93	1.32
SE (m)	0-30	0.04	0.05	0.04	0.01		0.13			0.04
	30-60	0.59	0.18	0.01	0.01		0.10			0.03
CD at 5%	0-30	0.15	0.18	0.12	-		0.42			0.01
	30-60	-	-	-	-	-	-	-	-	-

Table 4: Effect of gypsum on nutrient status of soil after harvest of the crop

Depth	Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})		Available S (kg ha^{-1})	
	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
Treatments								
T1	220.78	203.16	23.84	20.70	560.91	538.54	16.85	18.81
T2	223.51	201.15	23.52	19.91	559.93	536.13	23.68	19.79
T3	224.03	201.87	23.55	20.57	562.12	538.04	28.40	20.49
T4	226.63	199.29	23.93	19.65	565.57	538.87	32.31	20.50
T5	229.12	197.95	23.72	19.99	568.26	543.17	33.75	21.22
T6	230.04	201.03	23.24	20.40	570.98	543.98	38.76	21.89
T7	232.82	202.27	24.55	19.76	558.36	541.28	41.58	21.46
S E (m)	2.53	1.07	0.33	0.31	4.53	1.68	0.95	0.65
C.D. at 5%	-	-	-	-	-	-	2.93	-

6. Conclusion

Increasing level of gypsum improves physical and chemical properties of soil and higher improvement was found with higher doses of gypsum. However T_3 (1.5 t gypsum ha^{-1}) is sufficient to maintain enough electrolyte concentration to increase HC. Application of 5 t gypsum ha^{-1} improves Mean weight diameter, Aggregate stability and Water stable aggregates. Application of gypsum increases exchangeable Ca^{2+} and increases Ca/Mg ratio of soil and reduces exchangeable Na^+, ESP soil, which have favourable impact on hydraulic conductivity. Increasing level to gypsum also increased the availability of N at higher level.

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