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Effect of gypsum incubated organics used as an amendment for sodic soil in greengram

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Abstract
The use of organic amendments (Pressmud and FYM) either alone or in combination with gypsum or as gypsum incubated organics was compared in the present investigation with an aim to increase the efficiency of applied gypsum under gardenland conditions. A field experiment was carried out during 2016 in ADAC&RI, Tamil nadu comprising of eight treatments replicated thrice in a randomized block design. The treatment details are T1 – Control T2 – 50% GR (gypsum requirement) alone @ 5.2 t ha^{-1}, T3 - FYM @ 12.5 t ha^{-1} alone, T4 - 50% GR + FYM, T5 - 50% GR incubated FYM, T6 - pressmud (PM) @ 10 t ha^{-1} alone, T7 - 50% GR + PM and T8 - 50% GR incubated PM with RDF in field (RBD) experiments having three replications. Organic amendments *viz.*, PM and FYM were applied @ 10 t ha^{-1} and 12.5 t ha^{-1} respectively and also gypsum was applied @ 50% gypsum requirement (5.2 t ha^{-1}). The organic manures with or without gypsum or as gypsum incubated manures (FYM and PM) were applied basally and incorporated into the soil 30 days prior to sowing as per the treatment schedule. The results of the investigation revealed significant differences in pH, EC, exchangeable Ca^{2+} and Exchangeable sodium percentage (ESP) among the treatments in comparison with the control. Among the treatments, the highest reduction in ESP (13.42%) and pH (9.20 to 7.86) were recorded by the 50% GR incubated PM (T8). A significant difference was observed in the Number of pods per plant, Number of grains per pod and DMP among the treatments. The reduction in pH and ESP due to addition of 50% GR incubated PM and FYM observed in field experiment resulted in an increase in available nutrients which ultimately enhanced yield of green gram. The treatment T_8 recorded the highest grain yield of 457 kg ha^{-1} followed by T_7 (421 kg ha^{-1}) which was 34% and 24% increase in yield over application of 50% GR alone. Therefore, incorporation of gypsum incubated (enriched) organics increased the effectiveness of gypsum in reclaiming sodic soils under gardenland conditions where moisture is a limiting factor.

Keywords: electrical conductivity, gypsum, incubation (enrichment), exchangeable sodium percentage, green gram

Introduction
The total global area of salt-affected soils including saline and sodic soils was 831 M ha (Martinez-Beltran & Manzur, 2005) [27]. Soil sodicity is characterized by high pH, high water soluble and exchangeable sodium, low biological activity, poor physical properties and deficiency of many essential nutrients. Exchangeable sodium and pH decrease soil permeability, available water capacity and infiltration rates through swelling and dispersion of clays as well as slaking of soil aggregates (Lauchli & Epstein, 1990) [24]. These modifications may reduce the yield of crops growing on such soils. As the country's food requirements are mainly from land based farming, the pressure on agricultural land is high. Therefore increasing the productivity of sodic soils by developing low cost technologies using locally available resources is the need of the hour. Gypsum (GYP) is the most commonly used amendment due to its availability at low cost. Joachim *et al.* (2007) [21] attributed the beneficial effect of combined use of farm yard manure (FYM) and GYP on the reclamation of sodic soils. Being sparingly soluble in nature, to increase the efficiency of applied gypsum in the absence of sufficient moisture either through irrigation or rainfall becomes a challenging task. Under such conditions, use of organic sources as amendments plays a dual role, in not only increasing the solubility (Singh *et al.*, 2015) [38] of gypsum through the organic acids released during decomposition but also helps to improve the soil physico-chemical properties (Wahid *et al.*, 1998; Sardina *et al.*, 2003; Liang *et al.*, 2005; Tajada *et al.*, 2006) [43, 34, 24, 40]. The present study was therefore aimed to evolve an economically feasible and practically viable

management strategy through incubation of gypsum with organic amendments *viz.,* farm yard manure (FYM) and press mud (PM) which is an industrial byproduct that is abundantly available so as to hasten the solubilization of gypsum through organic acids formed during organic matter decomposition (Ramaswamy, 1999; Kumar and Verma, 2002; Nehra and Hooda, 2002; Rangaraj *et al.,* 2007; Jamil *et al*., 2008; Muhammad and Khattak, 2009) [32, 23, 29, 33, 20, 28] on reclaiming soil physico-chemical properties in a sodic soil and to evaluate greengram crop performance on these reclaimed soils.

Materials and Methods

Soil sampling and preparation

A representative composite surface soil sample (0 - 15 cm) was collected from the experimental site before the commencement of the experiment for initial soil properties. Collected soil samples were brought to the laboratory and spread on a polythene sheet and kept one day for air drying. In order to minimize soil heterogeneity, the samples were mixed thoroughly and sieved through 2 mm sieve. Sodicity indicator parameters, soil reaction (pH), and Exchangeable Sodium Percentage (ESP) of the initial soil were measured in soil saturated paste extract and the values were 9.20 dS m^{-1} and 29.0, respectively revealing that the soil of the experimental site is sodic (Ghafoor *et al*., 2004) [13].

Preparation of gypsum incubated organics

Mass production of gypsum incubated organics was done in the ADAC&RI, Trichy at Tamil Nadu. For this, PM and FYM was obtained from Anbil Dharmalingam Agricultural college and research Institute, Tamil Nadu. The 50% GR incubated organics were prepared by using heap method. Initially the powdered PM @ 10 t ha^{-1} and FYM @ 12.5 t ha^{-1} was mixed with fine grained gypsum @ 50% GR (5.2 t ha^{-1}) in separately. Water was added so as to maintain the 50 - 60% moisture content and heaped and covered with gunny bags to maintain the moisture level. The manure heaps were turned at weekly intervals (to provide adequate aeration, thorough mixing of organics with gypsum and uniform decomposition) and re-heaped, taking care to maintain the moisture level at 60% by sprinkling with water. The gypsum incubated organic manures were maintained for a period of 45 days. At the end of 45 days the gypsum incubated pressmud and FYM were applied to the field at required quantities as per the treatment schedule. Samples of 50% GR incubated PM and FYM were drawn from the compost heap then oven dried at 650 C for 24 h, ground to pass through a 2-mm sieve, and analysed for pH, EC, total C, N, P and K as well as Olsen-P, and NH_4OAc-K as per the standard procedure/ method.

Experimental design and treatments

The experiment was laid out in a randomized block design having plot size 5 * 4 m and plant spacing of 30 * 10 cm with the recommended doses of nitrogen (25 kg N ha^{-1}), phosphorus (50 kg P_2O_5 ha^{-1}) and potassium (25 kg K_2O ha^{-1-}) as well as other materials were computed as per the treatment combinations. Urea, super phosphate, muriate of potash and gypsum were used as the source of N, P, K and gypsum were used as the source of Ca (23%) and S (19%), respectively. The eight different treatments are Control (T_1), 50% gypsum requirement (GR) @ 5.2 t ha^{-1} alone (T_2), FYM @ 12.5 t ha^{-1} alone (T_3), 50% GR + FYM (T_4), 50% GR incubated FYM (T_5), pressmud (PM) @ 10 t ha^{-1} alone (T_6), 50% GR + PM (T_7) and 50% GR incubated PM (T_8) with RDF replicated thrice.

Soil analysis

Soil samples were collected from each plot at three physiological growth stages of greengram flowering (FS), pod formation (PF) and harvest stages (HS) and analysed for organic C (Walkley and Black 1934) [44], mineral N (Subbiah and Asija 1956) [39], Olsen P (Olsen *et al.* 1954) [30], NH_4OAc-K (Jackson 1973) [19] as well as exchangeable cations *viz.,* Ca, Mg, Na and K (Jackson 1973) [19].

Results and Discussion

Soil characterization was done before the start of the experiment. Results of physiochemical analysis of soils are shown in Table 1.

Table 1: Initial soil characteristics

S. No	Particulars	Values
1.	pH	9.20
2.	EC (dS m^{-1})	0.29
3.	Organic carbon (%)	0.43
4.	ESP	29.00
5.	Alkaline $KMnO_4$- N (kg ha^{-1})	221
6.	Olsen - P (kg ha^{-1})	19.30
7.	Neutral N NH_4OAc- K (kg ha^{-1})	156
8.	Available sulphur (mg kg^{-1})	0.39
9.	DTPA-Fe (mg kg^{-1})	11.80
10.	DTPA-Mn (mg kg^{-1})	9.02
11.	DTPA-Zn (mg kg^{-1})	0.45
12.	DTPA-Cu (mg kg^{-1})	1.10

Initial soil analysis showed that soil belongs to Inceptisol, Typic Ustropept taxonomy of Punjappur series. The results of analysis are presented in table 1. The soil was alkaline (pH-9.20) in reaction having low soluble salts. The textural analysis revealed that it belonged to sandy clay loam. The nutrient status of soil showed that it was low in organic carbon and available nitrogen (221 kg ha^{-1}), medium in available phosphorus and potassium.

Effect of amendments on soil pH

A significant change in soil pH was observed due to the application of 50% GR incubated PM (T_8), followed by 50% GR incubated FYM (T_5) which recorded markedly higher reduction in pH values (7.86 and 7.92) over control at all stages of observation. This was followed by combined application of gypsum and PM / FYM which may be due to the fact that gypsum provided Ca^{2+} to replace the sorbed Na^+ and the manure would have further boosted the process by producing organic acids and CO_2 to dissolve native $CaCO_3$ to liberate more Ca^{2+} for replacement of Na^+. This is in line with the findings of Alwai *et al.* (1980), Singh (1985) [37] and Tiwari and Jain (1992) [42]. Reduction in soil pH observed due to combined application of 50 % gypsum either with pressmud or FYM was also in consonance with earlier findings of Haynes and Naidu (1998) [17] who reported reductions in soil pH due to combined application of gypsum with FYM.

Interestingly, the slight decrease in the pH of the soil observed under no amendments (RDF alone) applied condition might have been due to the nitrification and acidification processes stimulated by application of fertilizers as well as by H^+ ions released by roots. The results are in concordance with the findings of Wang and Yang (2003) and Guo *et al.* (2010).

Effect of amendments on soil Electrical Conductivity

At all stages of crop growth significant difference in EC was observed among the treatments compared. The highest EC was recorded in the treatment receiving 50% GR incubated PM (T_8) irrespective of the stages of crop (1.03 and 0.99 dS m^{-1}) and this may be due to the presence of high soluble salts contributed by addition of pressmud. This was followed by the treatment T_5 receiving 50% GR incubated FYM (1.01 and 0.96 dS m^{-1}). The lowest EC was recorded in control (T_1) at all stages of crop growth (0.28 and 0.27 dS m^{-1}) and was on par with the treatment receiving FYM alone @12.5 t/ha (T_3) except at post harvest stage.

Increase in EC could be attributed to the higher amount of salts contributed by the inorganic NPK fertilizers as well as micronutrients which was uniformly added through soil application. The addition of organic amendments also influenced the electrical conductivity of soil. It was observed that the application of pressmud was more effective than FYM in reducing soil pH and contributing more salts resulting in an increase in EC at all stages of crop growth. Similar result was also reported by Dang and Verma (1996) [10], Pasricha *et al.* (1996) and Singh *et al.* (2015) [38]. Korai *et al.* (2015) reported increase in the EC values of post harvest soil samples with the application of biocompost.

Effect of amendments on soil Exchangeable cations (Ca +Mg)

The application of amendments either organic (FYM, PM) or inorganic (gypsum) had a profound influence on the exchangeable cations at all stages of crop growth. The exchangeable Ca, Mg and K were found to be higher in the treatment receiving 50% GR incubated PM (T_8) irrespective of the stage of crop while lower values were recorded in the control (T_1). The increase in exchangeable Ca and Mg may be due the addition of organic amendments *viz.*, pressmud, FYM with gypsum either in combination or as incubated form which might have resulted in an increase in these cations in soil solution due to dissolution of gypsum by the organic acids formed during decomposition of the organic amendments (Wong *et al.*, 2009). Besides, the addition of organic amendments may have also led to an increase in the Ca+Mg content of the soil (Ahmed *et al.*, 1988). Datta *et al.* (1983) concluded from their research work that pressmud increased the exchangeable Ca and Mg contents in the soil.

Effect of amendments on ESP

The effect of soil amendments on soil exchangeable sodium percentage is shown in Figure 6. The results indicated that application of amendments significantly reduced the ESP in all the treatments compared to the control soil. The incorporation of 50% GR incubated PM / FYM and 50% GR + PM were more effective in reducing the soil ESP as compared with organic and inorganic amendments applied alone or in combination. It can be noted that the best reduction in ESP was observed when 50% GR incubated PM and FYM was applied recording a value of 13.42 and 14.31 per cent. This value was much lower than the initial value (29 per cent). The results are in accordance with the findings of Choudhary *et al.* (2004) who reported that the addition of organic matter with gypsum decreased the ESP of the sodic and saline sodic soils. The decrease in soil ESP with addition of amendments (organic /inorganic) either alone or in combination may be attributed to increased Ca in soil solution as a result of addition of gypsum and organic sources which promoted Na displacement and its subsequent removal during irrigation to lower soil layers (Gharaibeh *et al.*, 2009 and 2011). Similarly, Abdel Fattah (2012) also reported a decrease in sodicity due to application of gypsum in combination with compost.

Effect of amendments on green gram yield

The yield of crop is a function of many factors, which includes soil, crop and climatic factors and the effective management of inputs. It is important to provide a favourable environment which could support the plant throughout its life span

The data on mean grain yield of greengram presented in table 2 showed that the plots receiving 50% GR incubated PM (T_8) was significantly higher (457 kg ha^{-1}) than control (T_1). This was followed by the treatments T_5 and T_7 which received 50% GR incubated FYM and 50% GR + PM, respectively which were statistically on par with each other but was significantly higher than the treatments T_2, T_3 and T_6 which received the sole application of 50 % gypsum, FYM and PM, respectively besides control (T_1).

The results suggest that addition of gypsum and organic amendments (PM and FYM) either solely or in combination or as gypsum incubated organics resulted in an increase in yield of greengram when compared to no amendment control (T_1) which may be attributed directly to the nutritional effect and indirectly through improved soil physical and chemical properties. The results confirm the findings of several researchers who reported increased yield due to integrated use of FYM plus gypsum (Sharma *et al.*, 2001; Sharma and Minhas, 2004 and Makoi and Ndakidemi, 2007), PM+G (Chauhan, 1995) and PM+G+FYM (Devitt *et al.*, 1981) than their sole application in terms of soil reclamation and crop yields.

However, 50% GR incubated PM (T_8) was found to be superior in recording the highest yield of 457 kg ha^{-1} which could be due to the additional nutrient availability along with improvement in physical characteristics of soil due to pressmud (Agarwal *et al.*, 1964; Chand *et al.*, 1977 and Manchanda *et al.*, 1989) [2, 6]. It may also be attributed to the favorable Ca^{2+}/Na^+ ratio in soil coupled with favourable effect of Ca^{2+} probably on maintaining cell membrane integrity and plant metabolism (Ashraf, 2004) [5]. The results are in confirmation with those reported by Hussain *et al.* (1986) [18] and Chaudhray *et al.* (1990).

The 50% GR incubated pressmud with 100% RDF was found to be the best amendment for gardenland crop under sodic soil condition.

Table 2: The effect of various amendments and their combination on soils after raising the crop for pod formation stage (45th day) followed by post-harvest stage (80th day) of field experiment

Treatments	Pod formation stage			Post harvest stage				
	pH	EC ($dS\ m^{-1}$)	Exch. Ca ($c\ mol\ (p^+)\ kg^{-1}$)	pH	EC ($dS\ m^{-1}$)	Exch. Ca ($c\ mol\ (p^+)\ kg^{-1}$)	ESP (%)	Grain yield ($kg\ ha^{-1}$)
T_1 - Control	9.14	0.28	8.74	9.12	0.27	8.80	28.05	170
T_2 - 50 % GR (alone)	8.64	0.47	9.69	8.48	0.47	9.73	17.97	341
T_3 - FYM (alone)	8.78	0.30	9.59	8.75	0.30	9.70	21.22	318
T_4 - 50 % GR + FYM	8.40	0.71	10.20	8.27	0.69	10.25	15.49	395
T_5 - 50 % GR incubated FYM	8.21	1.01	10.56	7.92	0.96	10.60	14.31	421
T_6 - PM (alone)	8.56	0.35	9.87	8.41	0.34	9.96	16.49	356
T_7 - 50 % GR + PM	8.39	0.72	10.68	8.10	0.72	10.74	14.45	406
T_8 - 50 % GR incubated PM	8.18	1.03	10.85	7.86	0.99	10.90	13.42	457
SED	0.14	0.01	0.20	0.15	0.01	0.21	0.44	8.85
CD (P = 0.05)	0.30	0.03	0.43	0.33	0.04	0.44	0.93	18.0

Conclusions

The results obtained from the present investigation clearly indicates the beneficial effect of gypsum incubated organics and mere conjoint application of organic and inorganic amendments in enhancing the soil fertility, nutrient content, uptake and yield of greengram in a sodic soil when compared to the sole application of either inorganic or organic amendments. The research highlighted the efficacy of 50% gypsum incubated organics (PM @ 10 t ha^{-1} and FYM @ 12.5 t ha^{-1}) for growing a successful gardenland crop in the absence of a suitable amelioration strategy under sodic conditions using the sparingly soluble gypsum where moisture is a limiting factor.

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