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Characterization of salt affected soils of Ongole division, Prakasam district, Andhra Pradesh

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Studies conducted in salt affected soils of Ongole division, Prakasam district of Andhra Pradesh. indicated that the pH was neutral to strongly alkaline (pH 6.5 to 9.1) in reaction and ECe were higher in surface soils (37.0 dS m^{-1}) than sub-surface soils (21.3 dS m^{-1}). Texturally they are loamy sand, clay loam, and clay. The organic carbon content of soils was low (0.42 %) and the soils of the region were calcareous (6.92 %). The cation exchange capacity (CEC) ranged from 9.50 to 79.70 with a mean of 48.17 c mol (p+) kg^{-1} of soil and the exchangeable Ca^{2+} and Mg^{2+} were above critical limit. The exchangeable sodium percentage (ESP) ranged from 1.69 to 48.99 with a mean of 11.57. Studies indicated a significant and positive correlation between CEC and clay content (r= 0.5942), exchangeable calcium showed significant and positive correlation with CEC (r= 0.5121**) and clay (r= 0.2206*) and exchangeable sodium also had highly significant and positive correlation with ESP (r= 0.6463**). These soils can be reclaimed with incorporation of gypsum or pyrites, organic manure and better management practices that decreased the ESP of soils.**

Key words: Salt affected soils, alkaline, saline, CEC, ESP, organic carbon, calcium carbonate

All soils contain some amount of soluble salts, which is essential for the healthy growth of plants. If the quantity of soluble salts in soil exceeds a certain value, the growth and yield of crops are adversely affected. Such soils, with excess soluble salts, are called the salt-affected soils. These soils are grouped into two classes depending upon the nature of soluble salts, physico- chemical characteristics, plant response and the management practices required for their reclamation namely, saline and alkali soils (Anonymous, 2004). Salt-affected soils adversely affect plant growth because of the total concentration of salts (salinity) in the soil solution and concentration of specific ions, especially sodium (sodicity). In order to assist in characterizing and managing salt-affected soils, techniques have been developed to measure and quantify the degree of soil salinity and sodicity. Salt-affected soils pose diverse problems and differ greatly from normal soils in respect of morphological features, physical properties and chemical characteristics. They show wide variations from place to place and have been distinguished into certain categories, the important ones being the saline and sodic soils (Tiwari et al., 1983). These regions pose serious problem for the productivity of crops. Salinity in this area is due to inherent salinity, as this area remained under the sea for a long period and high saline water table has made the agricultural lands saline and lateral sea water intrusion in the cultivated lands (Nayak et al., 2000). The important crops grown in the division are tobacco, cotton, jowar, chillies, groundnut, and horse gram.

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The characterizations of these soils is a pre-requisite for the profitable soil management and sustainable crop production. The present investigation was taken up to know the chemical characteristics of soils under different mandal of Ongole division.

Materials and Methods

The investigation was carried out during March, April and June, 2009 in Ongole division of Prakasam district, A.P comprising of 3,59,772 ha area, which lies between 14^{0} – 15' to 16^{0} – 18' N latitude and 78^{0} – 47' to 80^{0} – 40' E longitude. The average annual rainfall is 750 mm. One hundred representative soil samples (surface and sub-surface) were collected from twenty three mandals of Ongole division by following the random sampling technique. The soil samples were analysed for various physico-chemical properties. The pH and ECe were determined from the saturation extract as described by Jackson (1973). The soil organic carbon was estimated by wet digestion method of Walkley and Black (1934). The CEC and exchangeable cations were analysed as per the standards method of Bower *et al.* (1952), while the soil texture and free $CaCO_3$ were determined as per Piper, (1966). Correlation coefficients were worked out (Table 1).

Results and Discussion

Soil characteristics

The characteristics of soils of Ongole division revealed that the average pH of the surface and sub-surface soil samples ranged from 6.5 to 9.1 and 6.6 to 9.5 with mean values of 7.9 and 8.2, respectively (Table 2) indicating the soil reaction was from neutral to strongly alkaline. The per cent distribution of soil samples into different pH classes showed that 55 per cent of the surface and 33 per cent of sub-surface soil samples had pH less than 8.0 and 34 per cent of surface and 40 per cent of sub-surface soil samples had pH 8.0 to 8.5 whereas 11 and 27 per cent of soil samples, respectively had pH > 8.5 indicates strongly alkaline group. The distribution of soils into different pH classes was as suggested by CSSRI, Karnal (Anonymous, 1984). The relatively higher pH of the soil may be due to the calcareous nature of parent material, free $CaCO_3$ and high amount of alkaline earth metals not clear. The pH was significantly and positively correlated with $CaCO_3$ (r= 0.2111*) (Table 1). The pH showed an increase with increase in salinity except in strongly saline soils which was attributed to the dominance of neutral soluble salt. The pH is slightly increased with increasing soil depth (Chaudhary *et al.,* 2006).

Table 1. Correlation coefficient (r) between different physico-chemical properties of soil

Soil Parameter	r- value
pH vs CaCO3	0.2111*
pH vs Exchangeable Na	0.4704**
pH vs ESP	0.5590**
EC vs OC	0.3048**
EC vs CEC	0.2066*
Exchangeable Ca vs CEC	0.5121**
Exchangeable Ca vs ESP	-0.2696**
Exchangeable Na vs CEC	0.5107**
Exchangeable Na vs ESP	0.6463**
Exchangeable Mg vs CEC	0.5229**

* and ** Significant at 5 and 1 per cent level, respectively.

The ECe of surface and sub-surface soil samples varied from 0.03 to 37.0 and 0.04 to 21.3 dS m^{-1} with a mean of 4.1 (moderately saline) and 2.2 dS m^{-1} (slightly saline) (Table 2) respectively, indicating higher concentration of soluble salts especially in the surface soils. The ECe values were high in surface soils and decreased with depth. During the dry period, the water table moves below the root zone leaving behind the salts near the surface leading to higher concentration of soluble salts on the surface. Similar results were earlier reported by Mandal and Sharma (1997). The distribution of ECe values into five classes showed that 66 per cent of surface and 83 per cent of sub-surface soil samples had ECe < 4.0 dS m^{-1}, 22 per cent of surface and 11 per cent of sub-surface samples had moderately saline (4.0 to 8.0 dS m^{-1}) and the rest of 12 and 6 per cent of surface and sub-surface samples, respectively had ECe > 8.0 dS m^{-1} as classified by CSSRI, Karnal (Anonymous, 2004). Texturally these soils varied from loamy sand to clay in texture with percentage sand, silt and clay content ranging from 30.00 to 93.20, 2.40 to 30.50 and 4.30 to 49.90 per cent with mean values of 55.63, 13.60 and 30.76 per cent, respectively. The lowest clay content was registered in the soils of Kothapatnam mandal and the highest was in Ponnaluru mandal.

The organic carbon content of surface and sub-surface soil samples varied from 0.06 to 1.29 per cent and 0.05 to 1.08 per cent with a mean of 0.42 and 0.26 per cent, respectively. The organic carbon content of moderately saline soils was higher in surface soils and decrease gradually with an increase in depth. This was similar to Sharma *et al.* (2004). Bhattacharyya *et al* . (2004) also reported that the organic carbon was lower in soils having higher pH and calcium carbonate. The average calcium carbonate content of surface and sub-surface soils ranged from 0.72 to 23.52 and 0.5 to 24.75 per cent with a mean value of 6.92 and 7.57 per cent respectively, indicating calcareous nature. The low range of calcium carbonate content of surface samples was found in Marturu mandal, while the higher range was observed in Ballikurava mandal. Sub-surface soil samples have high $CaCO_3$ content (mean 7.57%) compared to surface soil samples (mean 6.92%). Kanzaria *et al*. (1982) observed that high content of $CaCO_3$ in salt-affected soils of coastal area.

The cat ion exchange capacity (CEC) of soils of Ongole division ranged between 9.50 to 79.70 c mol (p^+) kg^{-1} of soil with a mean of 48.17 c mol (p^+) kg^{-1} soil. Except Kothapatnam, Kandukuru, Pedacherlopalli and Kanigiri mandals (means 17.15, 19.59, 11.96 and 19.56 c mol (p^+) kg^{-1} of soil respectively), the mean CEC of all other soils were reasonably high ranging from 28.87 (Ponnaluru mandal) to 77.15 (Maddipadu mandal) c mol (p^+) kg^{-1} of soil. The high CEC of soil of Ongole division might be due to smectite types of clay, reasonably CEC values were significant and positive correlation with clay content (r= 0.5942**). Similar results were reported by Fitzpatrick and Naidu (1995) in Kapunda, South Australia and Yeresheemi *et al*. (1997) in salt-affected Vertisols of Upper Krishna Command, Karnataka. The exchange complex of all the soil samples were dominated by Ca^{2+} followed by Mg^{2+}, Na^+ and K^+ ions. Among the exchangeable cations the exchangeable calcium contributes more on CEC rather than other cations. This can be confirmed by exchangeable calcium showed significant and positive correlation with CEC (r= 0.5121**) and clay (r= 0.2206*). Similar results were also reported by Sharma *et al*. (2004) in salt-affected soils of Southern Rajasthan.

The ESP of soils ranged from 1.69 to 48.99 with a mean of 11.57. The ESP of more than 15 was observed in Marturu, Karamchedu and Ballikurava mandals. Among the hundred surface soil samples estimated, 26 per cent of samples were found to be more than 15 ESP (sodic group) value and 19 per cent of samples were observed in between 10 to 15 (moderate group) remaining, 55 per cent of soil samples were categorized in non-sodic group (< 10 ESP).

Table 2. Physico-chemical properties of surface soil samples in Ongole division,Andhra Pradesh

S. No.	Mandal	No. of samples	pH	ECe (dS m-1)	ESP	OC (%)	Clay (%)	$CaCO_3$ (%)	CEC	Ex. Ca	Ex. Mg	Ex. Na	Ex. K
									(C mol (p+) kg-1)				
1	Ongole	3	7.3-8.1 (7.5)	2.41-37.0 (14.54)	4.80-9.22 (7.17)	0.23-0.54 (0.36)	36.4-45.5 (40.7)	1.92-2.88 (2.40)	59.78-67.93 (64.44)	20.50-66.00 (41.83)	7.00-20.50 (11.83)	3.26-5.98 (4.57)	0.92-1.60 (1.23)
2	N.G.Padu	9	7.4-8.7 (7.9)	0.16-36.0 (8.96)	5.32-21.93 (11.78)	0.14-0.74 (0.41)	21.5-45.1 (33.2)	0.96-10.56 (4.69)	46.20-78.80 (63.75)	17.50-43.40 (33.10)	4.50-20.60 (11.96)	3.40-16.56 (7.56)	0.41-1.76 (0.87)
3	Inkollu	5	7.2-8.4 (7.9)	0.88-9.3 (4.1)	6.50-17.07 (10.45)	0.33-1.13 (0.57)	36.4-43.1 (38.5)	2.64-10.08 (5.76)	57.07-77.45 (70.79)	24.80-38.40 (33.76)	10.4-16.00 (13.68)	5.03-12.06 (7.21)	0.76-11.04 (2.98)
4	J.Panguluru	7	7.3-8.4 (7.8)	2.30-25.0 (7.4)	5.27-16.01 (9.56)	0.33-0.98 (0.63)	30.0-47.5 (37.5)	2.16-18.24 (10.25)	44.84-77.40 (66.94)	22.00-54.50 (34.47)	3.00-16.40 (8.11)	3.81-10.40 (6.16)	0.13-1.76 (0.61)
5	Korisapadu	4	6.8-8.5 (7.9)	2.54-6.3 (4.16)	5.24-16.50 (10.93)	0.3-0.39 (0.34)	29.6-34.0 (31.8)	6.00-14.64 (11.52)	57.07-74.20 (67.13)	34.20-41.00 (37.73)	2.00-11.20 (7.65)	2.99-10.76 (7.45)	0.69-0.72 (0.70)
6	Marturu	5	7.1-8.9 (8.2)	1.05-19.0 (6.34)	1.72-23.63 (16.16)	0.48-0.78 (0.65)	22.3-40.1 (33.9)	0.72-17.28 (7.78)	43.48-77.45 (62.95)	16.50-33.50 (25.50)	2.50-8.00 (6.50)	0.89-16.59 (10.37)	0.19-4.00 (1.20)
7	Maddipadu	3	8.2-8.3 (8.2)	0.42-5.3 (2.71)	6.56-15.77 (9.79)	0.24-0.27 (0.26)	35.1-45.6 (38.5)	5.28-13.68 (10.56)	75.20-78.80 (77.15)	33.00-40.50 (37.67)	5.50-11.00 (7.67)	5.17-12.21 (7.56)	0.47-0.68 (0.60)
8	Addanki	3	7.4-8.2 (7.7)	2.00-5.2 (3.23)	5.55-7.44 (6.76)	0.36-0.60 (0.47)	15.1-37.6 (25.9)	7.20-12.96 (9.52)	52.99-78.20 (62.75)	31.50-36.00 (34.17)	5.50-7.00 (6.17)	3.17-5.71 (4.27)	0.36-0.83 (0.50)
9	Mundlamuru	6	7.6-8.1 (7.8)	1.28-5.3 (3.52)	5.11-15.98 (9.70)	0.12-1.29 (0.58)	22.5-37.6 (31.2)	2.64-21.36 (11.40)	32.61-58.50 (43.04)	17.50-33.50 (27.67)	1.50-7.50 (4.00)	2.72-6.26 (3.90)	0.20-0.61 (0.41)
10	Darsi	2	7.0-7.7 (7.3)	2.89-3.3 (3.1)	7.96-10.00 (8.98)	0.92-1.04 (0.98)	24.6-39.5 (32.1)	6.72-13.68 (10.20)	46.20-52.99 (49.60)	31.00-36.50 (33.75)	1.48-1.50 (1.49)	4.22-4.62 (4.42)	0.24-0.44 (0.34)
11	Podili	3	7.7-8.4 (8.0)	2.10-2.3 (2.2)	10.43-20.02 (13.72)	0.29-0.77 (0.48)	27.5-33.5 (29.6)	4.56-18.96 (10.40)	24.46-32.61 (29.44)	15.50-21.50 (18.67)	2.50-4.50 (3.67)	3.26-4.90 (3.88)	0.23-1.18 (0.61)

13	S. N. Padu	3	8.3-8.6 (8.4)	0.6-2.3 (1.5)	5.82-48.99 (27.33)	0.20-0.66 (0.50)	30.1-36.9 (34.2)	3.36-18.96 (12.16)	25.82-58.42 (40.76)	13.50-36.50 (23.33)	4.50-5.50 (5.00)	3.40-12.65 (8.80)	0.15-1.23 (0.78)
14	Karamchedu	2	7.2-7.9 (7.6)	5.3-15.5 (10.4)	6.51-6.85 (6.68)	0.47-1.08 (0.77)	35.1-42.6 (38.9)	2.40-5.76 (4.08)	71.50-72.00 (71.75)	43.00-50.00 (46.50)	12.00-21.50 (16.75)	4.69-4.90 (4.80)	0.10-0.12 (0.11)
15	Yaddanapudi	4	7.3-8.4 (7.9)	2.5-4.6 (3.6)	4.83-16.99 (10.75)	0.27-0.59 (0.43)	20.1-37.6 (30.7)	3.36-14.64 (6.90)	44.84-78.30 (65.41)	23.00-48.50 (39.13)	5.00-14.00 (9.50)	3.67-10.62 (6.50)	0.14-1.11 (0.69)
16	Ballikurava	4	7.0-9.1 (8.0)	0.8-7.1 (5.2)	6.04-37.71 (17.70)	0.24-0.96 (0.55)	25.1-38.2 (32.1)	10.80-23.52 (17.52)	40.76-72.01 (58.08)	16.50-36.00 (26.38)	6.00-11.50 (8.50)	4.08 -22.0 (9.69)	0.40-1.84 (1.72)
17	Kothapatnam	6	7.3-7.7 (7.5)	6.3-8.5 (7.6)	1.69-14.02 (9.95)	0.15-0.47 (0.32)	4.3-10.8 (6.5)	1.44-6.00 (3.12)	9.50-32.50 (17.15)	23.50-41.50 (28.67)	3.00-10.50 (6.83)	0.55-2.35 (1.32)	0.20-1.60 (0.75)
18	Ulavapadu	3	7.0-8.4 (7.6)	0.5-5.6 (2.5)	5.71-9.72 (8.06)	0.42-0.53 (0.44)	25.1-40.1 (33.4)	1.68-3.60 (2.56)	57.07-79.67 (68.36)	7.00-16.50 (10.83)	2.50-7.00 (4.00)	3.26-7.75 (5.66)	0.27-0.67 (0.54)
19	Zarugumalli	2	7.6-8.2 (7.9)	3.2-6.2 (4.7)	6.53-14.72 (10.63)	0.09-0.24 (0.17)	14.9-45.4 (30.1)	1.92-3.12 (2.52)	13.59-70.80 (42.20)	7.50-36.50 (21.75)	3.00-6.00 (4.50)	2.00-4.62 (3.31)	0.20-2.32 (1.26)
20	Kandukuru	5	6.5-8.3 (7.3)	0.01-0.20 (0.1)	4.68-12.51 (9.49)	0.12-0.33 (0.21)	31.9-36.9 (34.7)	1.68-3.60 (2.78)	13.59-27.17 (19.59)	8.00-28.50 (15.40)	1.50-8.50 (4.20)	0.64-3.40 (1.95)	0.20-0.67 (0.45)
21	Ponnaluru	8	8.0-8.8 (8.4)	0.1-0.4 (0.2)	5.63-25.91 (14.14)	0.15-0.32 (0.21)	15.1-49.9 (30.2)	2.16-5.28 (3.57)	16.30-39.40 (28.87)	19.50-42.00 (31.13)	1.00-5.00 (3.13)	2.04-5.81 (3.59)	0.21-0.73 (0.48)
22	Pedacherlopalli	5	7.4-8.9 (8.3)	0.1-0.4 (0.2)	4.99-24.29 (12.67)	0.06-0.51 (0.26)	15.1-26.9 (21.8)	3.36-6.48 (5.14)	10.19-14.95 (11.96)	6.00-16.00 (12.90)	1.50-4.00 (2.60)	0.55-3.13 (1.56)	0.31-1.44 (0.83)
23	Kanigiri	5	7.4-8.3 (7.9)	0.0-0.1 (0.1)	7.27-17.77 (11.91)	0.18-0.41 (0.27)	15.1-31.9 (25.1)	2.16-7.92 (4.56)	18.34-22.42 (19.56)	15.50-29.50 (20.70)	1.50-2.00 (1.60)	1.50-3.50 (2.31)	0.27-0.59 (0.36)
	Range Overall mean		6.5-9.1 (7.88)	0.01-37.0 (4.)	1.69-48.99 (11.57)	0.06-1.29 (0.42)	4.3-49.9 (30.8)	0.72-23.52 (6.92)	9.50-79.70 (48.17)	6.00-66.00 (28.37)	1.00-21.50 (6.71)	0.55-22.03 (5.22)	0.10-11.04 (0.82)

Values in parentheseis are means

Table 3. Physical and chemical properties of sub-surface soil samples in Ongole division, Andhra pradesh

S. No.	Mandal	No. of samples	pH	ECe (dS m^{-1})	OC (%)	$CaCO_3$ (%)
1	Ongole	3	7.0-8.1 (7.7)	2.1-15.3 (7.4)	0.24-0.36 (0.29)	2.50-5.25 (3.67)
2	N.G.Padu	9	7.5-8.8 (8.3)	0.1-15.6 (3.9)	0.05-0.44 (0.21)	1.00-10.75 (4.72)
3	Inkollu	5	8.2-8.9 (8.4)	0.1-4.3 (1.6)	0.09-0.42 (0.25)	4.00-11.50 (6.20)
4	J.Panguluru	7	7.5-8.6 (8.1)	0.5-21.3 (5.8)	0.12-0.51 (0.27)	1.00-23.75 (11.32)
5	Korisapadu	4	7.9-8.6 (8.3)	0.1-3.6 (1.7)	0.09-0.18 (0.14)	6.00-13.75 (10.44)
6	Marturu	5	7.7-9.5 (8.5)	0.3-11.3 (3.4)	0.17-0.35 (0.25)	1.25-18.00 (11.20)
7	Maddipadu	3	8.1-8.6 (8.3)	0.2-2.3 (1.5)	0.06-0.09 (0.08)	4.00-13.25 (9.83)
8	Addanki	3	8.1-8.6 (8.3)	0.8-3.1 (1.8)	0.05-0.47 (0.28)	9.00-13.25 (10.50)
9	Mundlamuru	6	7.5-8.4 (8.1)	0.5-2.3 (1.6)	0.09-1.08 (0.32)	1.00-24.75 (12.58)
10	Darsi	2	7.9-8.0 (7.9)	2.2-2.6 (2.4)	0.47-0.90 (0.68)	6.75-16.25 (11.50)
11	Podili	3	8.2-8.8 (8.54)	0.3-1.6 (1.1)	0.18-0.36 (0.29)	4.25-24.00 (12.50)
12	Marripudi	3	7.2-7.9 (7.6)	0.01-1.9 (0.7)	0.27-0.30 (0.29)	1.00-6.50 (3.83)
13	S. N. Padu	3	7.8-9.1 (8.5)	0.1-1.3 (0.7)	0.17-0.48 (0.38)	3.50-23.75 (14.25)
14	Karamchedu	2	7.1-8.3 (7.7)	2.6-8.6 (5.6)	0.33-0.99 (0.66)	3.20-6.00 (4.60)
15	Yaddanapudi	4	8.1-8.8 (8.5)	1.6-3.2 (2.3)	0.24-0.42 (0.33)	3.75-15.50 (7.56)
16	Ballikurava	4	8.3-9.1 (8.7)	0.1-5.3 (3.3)	0.26-0.51 (0.38)	11.25-20.75 (16.19)
17	Kothapatnam	6	7.0-8.8 (7.8)	2.4-5.6 (4.3)	0.17-0.44 (0.23)	0.50-6.50 (2.79)
18	Ulavapadu	3	7.2-8.5 (7.7)	0.01-4.3 (1.5)	0.33-0.42 (0.37)	4.25-6.00 (5.33)
19	Zarugumalli	2	8.2-8.3 (8.3)	1.6-4.5 (3.01)	0.09-0.38 (0.23)	2.00-3.75 (2.88)
20	Kandukuru	5	6.6-8.3 (7.4)	0.01-0.1 (0.1)	0.08-0.15 (0.11)	1.75-4.00 (3.10)
21	Ponnaluru	8	8.2-9.2 (8.5)	0.01-1.0 (0.4)	0.12-0.24 (0.17)	2.50-6.00 (4.04)
22	Pedacherlopalli	5	7.6-9.4 (8.6)	0.01-0.3 (0.1)	0.08-0.45 (0.23)	3.75-7.00 (5.55)
23	Kanigiri	5	7.5-8.4 (8.0)	0.01-0.1 (0.01)	0.14-0.29 (0.20)	2.50-8.25 (5.10)
	Range		6.6-9.5	0.01-21.3	0.05-1.08	0.50-24.75
	Overall mean		(8.2)	(2.2)	(0.26)	(7.57)

Values in parentheses are means

Note: N.G.Padu- Naguluppalapadu; J.Panguluru- Janakavaram Panguluru; S.N.Padu- Santhanootlapadu

The distribution of soil samples into different ESP classes as suggested by CSSRI, Karnal (Anonymous, 2004). The relatively heavier texture of the soils, exchangeable sodium, arid climate, and proximity to sea, soil erosion and low -lying area with poor drainage could be attributed as probable reasons for the higher ESP observed in these soils (Polara *et al*., 2006). Among the exchangeable cations sodium was highly significant with positive correlation with ESP (Table 1).

All the soil samples were neutral to strongly alkaline in reaction, non-saline to very strongly saline and low in organic carbon in both surface and surface samples. The soils were calcareous, with high calcium carbonate content. Texturally they were loamy sand, clay loam and clay. The cation exchange capacity of the soils was high indicating a high sorption capacity of the soils. Exchangeable calcium was the most dominant cation followed by magnesium, sodium and potassium. Among the 100 samples estimated 26 per cent of samples showed more than 15 ESP (sodic group) value and 19 per cent of samples in between 10 to 15 (moderate group). This soils if reclaimed will contribute a major share to the total production of the district.

The salt build-up, soil alkalization and rising water table affected soil productivity. Among the hundred surface soil samples estimated, 26 per cent of samples showed more than 15 ESP (sodic group). The alkali soils can be reclaimed with small quantity of amendments and preferably with better soil and water management practices. Gypsum is the most common material used to supply calcium for sodic soil reclamation. Elemental sulphur can also be used for reclamation of sodic soils when free lime exists in the soil.

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