



Effect of amendment sources in sodic soil under subsurface drainage system on yield and nutrient uptake of maize

AT Gedam^{1*}, SR Shelke², Koyal Abhang¹

¹ MSc Student, Department of Soil Science and Agricultural Chemistry, PGI, MPKV, Rahuri, Ahmednagar, Maharashtra, India

² Assistant Professor, Department of Soil Science and Agricultural Chemistry, MPKV, Rahuri, Ahmednagar, Maharashtra India

Abstract

The present study was conducted at Post Graduate Institute, Research Farm, Department of Soil Science and Agricultural Chemistry, MPKV, Rahuri, during *Kharif* 2019. The experiment was laid out in a randomized block design with three replication and twelve treatments. The treatment comprised of T₁: Absolute control, T₂: Gypsum as per 100% GR, T₃: Elemental sulphur as per 1/5th of GR, T₄: Zeolite @ 600 kg ha⁻¹, T₅: Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹, T₆: Gypsum as per 50% GR + zeolite @ 600 kg ha⁻¹, T₇: Gypsum as per 100% GR + zeolite @ 300 kg ha⁻¹, T₈: Gypsum as per 50% GR + zeolite @ 300 kg ha⁻¹, T₉: Elemental sulphur as per 1/5th of GR + zeolite @ 600 kg ha⁻¹, T₁₀: Elemental sulphur as per 50% of 1/5th GR + zeolite @ 600 kg ha⁻¹, T₁₁: Elemental sulphur as per 1/5th of GR + zeolite @ 300 kg ha⁻¹ and T₁₂: Elemental sulphur as per 50% of 1/5th GR + zeolite @ 300 kg ha⁻¹. The biomass production in maize crop grown on sodic soils under SSD (Subsurface drainage) field in terms of their fresh and dry matter yield mainly depends on uptake of nutrient and micronutrient by maize crop. Total uptake of nitrogen, phosphorus and potassium by maize crop were found to be higher (132.77, 27.14 and 134.46 kg ha⁻¹, respectively) in treatment Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹. Total uptake of iron, zinc, manganese and copper were found to be significantly higher (2034, 1134, 1443 and 805 g ha⁻¹, respectively) in treatment Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹. The grain and stover yield of maize was significantly highest recorded in treatment Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹ (53.8 and 62.44 q ha⁻¹). Therefore, based on above findings, application of Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹ along with the FYM and general recommended dose of nutrients (10 t ha⁻¹ FYM + 120:60:40, N:P₂O₅:K₂O kg ha⁻¹) to maize in SSD field was found beneficial for reclamation of sodic soil, increase in availability of nutrients in soil, total uptake of macro and micronutrients and higher grain and stover yield of maize grown in sodic soil under SSD system.

Keywords: subsurface drainage, gypsum, elemental sulphur, zeolite, sodic soil, maize

Introduction

Maize is medium salt tolerant crops, leafy stalk whose kernels have seeds inside. Maize belongs to the tribe *Maydeae* of the grass family *Poaceae*. “*Zea*” was derived from an old Greek name for a food grass. The genus *Zea* consists of four species of which *Zea mays L.* is economically important. The other *Zea sp.*, referred to as teosinte, is largely wild grass native to Mexico and Central America. The number of chromosomes in *Zea mays* is 2n = 20.

Maize is called the ‘Queen of Cereals’, also known as corn, is a cereal grain that was first grown by people in Central America. It is now the third most important cereal crop in the world. Maize is cultivated globally being one of the most important cereal crops worldwide. Globally, it is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 per cent (782 MT) in the global grain production. The United States of America (USA) is the largest producer of maize contributes nearly 35 per cent of the total production in the world and maize is the driver of the US economy. The USA has the highest productivity (> 9.6 t ha⁻¹) which is double than the global average (4.92 t ha⁻¹). Whereas,

the average productivity in India is 2.43 t ha⁻¹ (Murdia *et al.*, 2016) [1].

In India maize containing area, production and yield in 2016-17 is 9.63 million hectare, 25.90 million tonnes and 2689 kg ha⁻¹ respectively. In Maharashtra maize containing area, production and yield in 2016-17 is 1.15 million hectare, 3.45 million tonnes and 3009 kg ha⁻¹ respectively. (Anonymous, 2019) [2]. India produces about 2% the world’s maize produce. Karnataka is the leading producer of maize in India producing around 16% of India’s total Maize production. Karnataka is followed by Telangana & Bihar which together contribute 20% to India’s maize production basket. Maharashtra, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Rajasthan and Uttar Pradesh are other maize producing states of India (Kumar *et al.*, 2014) [3].

About 71% of maize in India is produced in the *Kharif* season. Karnataka, Madhya Pradesh, Tamil Nadu, Maharashtra, Telangana, UP & Rajasthan produce *Kharif* Maize, with Karnataka being the leader. Bihar, Andhra Pradesh & Tamil Nadu are states which produce *rabi* maize crop. *Rabi* is the primary crop of Bihar and Andhra Pradesh. Tamil Nadu produces 40% crop in *rabi*.

According to one estimate (Mandal *et al.*, 2010) ^[4] an area of 6.74 M ha in India suffers from salt accumulation out of which 3.78 M ha (~56 per cent) are sodic while, 2.96 M ha (44 Per cent) are saline soils and in Maharashtra total area under salt affected soil is 0.60 M ha out of which saline soil contain 0.18 M ha and sodic soil having 0.42 M ha. Sodic soils are those which have an exchangeable sodium percentage (ESP) of more than 15, pHs values will be more than > 8.5, and ECe will be < 4 dSm⁻¹. Excess exchangeable sodium has an adverse effect on the physical and nutritional properties of the soil (Richards, 1968) ^[7] with consequent reduction in crop growth, significantly or entirely.

For reasonably quick results cropping must be preceded by the application of soil amendments gypsum, followed by leaching for removal of salts derived from the reaction of the amendment with the sodic soil, that leachate are drain out by installation of subsurface drainage system in soil (Goel and Tiwari, 2015) ^[5]. Drainage system may be surface and sub-surface. Surface drainage is draining off excessive surface ponding where subsurface is lowering the root zone accumulation and the water table. Out of various methods of drainage systems subsurface drainage system will be most effective. Sub-surface drainage performed by fixing perforated PVC or clay tiles underground in a grade and draining an accumulated salt along with water to common outlet and then out of the field (Padalkar *et al.*, 2012) ^[6].

Material and Methods

Layout and Experimental Design

A field experiment on sodic soil was conducted during *kharif* 2019, at Post Graduate Institute Research Farm of Department of Soil Science and Agricultural Chemistry, MPKV. Rahuri, Dist. Ahmednagar, Maharashtra (India) with maize as a test crop. The experiment was laid out in a randomized block design with 12 treatments and 3 replications. The gross plot size was 4.5 m x 3.0 m i.e. 13.5 m² and net plot size was 3.0 m x 2.6 m i.e. 7.8 m². The recommended spacing of 75 cm x 20 cm was adopted for dibbling of maize. The general recommended dose of nutrients (120:60:40 kg ha⁻¹ N, P₂O₅ and K₂O, respectively) were given to maize as per treatment details except T₁ at the time of dibbling of maize.

The subsurface drainage system was already installed at field with laterals spacing of 30 m apart and the experiment was laid on the same site. PVC, corrugated perforated pipe is used, perforation size is 20×15 mm, diameter is 80 mm OD and slope given to the drain pipe is 0.2 percent.

Soils Characteristic

Textural class was clayey, bulk density of experimental soil was 1.58 Mg m⁻³ and hydraulic conductivity was slow (0.20 cm h⁻¹). The chemical properties of experimental soil showed strongly alkaline in reaction (pHs 8.48) with total soluble salts content (ECe) was 3.12 dSm⁻¹. Soil fertility was low in available nitrogen (143.24 kg ha⁻¹), low in available phosphorous (9.15 kg ha⁻¹) and very high in available potassium (457.82 kg ha⁻¹) content. The initial soil micronutrients *viz.* Fe, Mn, Zn and Cu status were sufficient in range 4.53, 5.07, 0.42 and 2.58 mg kg⁻¹, respectively. The exchangeable sodium percentage (ESP) and sodium

adsorption ratio (SAR) of soil were 16.62 and 12.54, respectively.

Application of Amendments

Amendments (Gypsum, Elemental sulphur and Zeolite) applied as per treatment with farm yard manure @ 10 t ha⁻¹ to all treatment plots except T₁.

The treatment comprised of T₁: Absolute control, T₂: Gypsum as per 100% GR, T₃: Elemental sulphur as per 1/5th of GR, T₄: Zeolite @ 600 kg ha⁻¹, T₅: Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹, T₆: Gypsum as per 50% GR + zeolite @ 600 kg ha⁻¹, T₇: Gypsum as per 100% GR + zeolite @ 300 kg ha⁻¹, T₈: Gypsum as per 50% GR + zeolite @ 300 kg ha⁻¹, T₉: Elemental sulphur as per 1/5th of GR + zeolite @ 600 kg ha⁻¹, T₁₀: Elemental sulphur as per 50% of 1/5th GR + zeolite @ 600 kg ha⁻¹, T₁₁: Elemental sulphur as per 1/5th of GR + zeolite @ 300 kg ha⁻¹ and T₁₂: Elemental sulphur as per 50% of 1/5th GR + zeolite @ 300 kg ha⁻¹.

Plant analysis

The plant and grain samples were collected at harvest of maize. The samples were air dried in shade and then dried in oven at 70°C till constant weight. The whole plant sample of each treatment was ground through a stainless steel Willey mill after oven drying. Digestion of plant and grain sample was done and used for estimation of nutrient concentration *viz.* N, P, K and micronutrients Fe, Zn, Mn and Cu by using standard methods. Total N: Micro-Kjeldahl (Parkinson and Allen 1975) ^[8], Total P: Vanadomolybdate yellow colour method in nitric acid (Jacson 1973), Total K: Flame photometry (Chapman and Pratt, 1961) ^[10] and Total micronutrient (Fe, Mn, Zn and Cu) Atomic absorption Spectrophotometry (Zososki and Burau 1977) ^[11].

Uptake of Nutrient

The uptake of major and minor nutrient were worked out by multiplying dry matter accumulation to N, P, K, Fe, Mn, Zn and Cu concentration at harvest by using the following formula.

$$\text{Uptake of Nutrients (Kg ha}^{-1}\text{)} = \frac{\text{Total dry matter (Kg ha}^{-1}\text{)} \times \text{Concentration of elements (\%)}}{100}$$

$$\text{Uptake of micronutrients (g ha}^{-1}\text{)} = \frac{\text{Total dry matter (Kg ha}^{-1}\text{)} \times \text{Conc. of elements (mg kg}^{-1}\text{)}}{100}$$

Biometric Observation

The dry matter yield of stover and grain per net plot of maize in q ha⁻¹ was recorded.

Results and Discussion

Effect of amendments on nutrient uptake in subsurface drainage field Nutrient (NPK) uptake

The sodic soil ameliorated with T₅: Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹ recorded significantly higher uptake of nitrogen, phosphorus and potassium at harvest by maize (132.77, 27.14 and 134.46 kg ha⁻¹, respectively). The increased nutrient uptake by maize on sodic soils by gypsum application might be because of gypsum provides the sufficient amount of calcium in soil and soil solution, these calcium exchange the excesses sodium from exchange site of

clay and leached out through SSD system from soil. The replacement of sodium from sodic soil decreased soil pH, electrical conductivity, improves the chemical and physical properties of soil, as well as workability of soil. These factors make the congenial condition in rhizosphere for nutrient absorption by maize crop. Similar results were observed by Jadhao *et al.* (2003) [12].

Micronutrient (Fe, Mn, Zn and Cu) Uptake

The micronutrients *viz.* Fe, Mn, Zn and Cu uptake was significantly superior over all the treatments in T₅: Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹ by maize (2034, 1443, 1134 and 805 g ha⁻¹, respectively). The availability of micronutrients in salt affected soils is mainly controlled by soil pH, concentration of salts in the soil solution, organic matter content and the interaction between crops and micronutrients. Micronutrient availability in salt affected soils is very complex. These constrains of micronutrient availability in sodic soil might be overcome by amending with gypsum as per gypsum requirement. The addition of gypsum in sodic soils provides sufficient amount of calcium, which plays crucial role to replace the predominant Na⁺ cation from exchange site. The exchanged Na⁺ by Ca²⁺ of gypsum loss from soil leads to decrease the pH, ESP, SAR and increased CEC as well as avoid decomposition of organic matter from sodic soils. Preserving the organic matter in soil by replacing Na⁺ by Ca²⁺ improves the soil aggregation, aeration and ultimately increased biodiversity. This might be reasons for the increased micronutrient uptake of maize crop. This result indicated that, none of the chemical amendments are comparable for micronutrient uptake of maize crop to gypsum amendment of sodic soil as per 100 percent gypsum requirement. Similar results were observed by Jadhao *et al.* (2003) [12].

Effect of Amendments on Yield of Maize in Subsurface Drainage Field

Sodic soils are soils which contains excess exchangeable sodium which adversely affects the most of crop plants. Adverse effects of sodic soil are the degradation of soil physical properties and nutritional properties with consequent reduction in crop growth significantly or entirely. Sodic soils can be improved by ameliorating with organic or inorganic amendments for their reclamation. The fundamental principle which governed the reclamation of sodic soils was the

removal of part or most of exchangeable sodium and its replacement by calcium ions and other preferred cations such as Mg and K in the root zone. This involved the use of soluble calcium salt such as gypsum, calcium chloride, acid or acid forming substances, including elemental sulphur, iron pyrite and some time the use of calcium salt of low solubility like ground limestone. In view of use of chemical amendments were studied to improve the yield of maize grown on sodic soils in SSD field during 2019.

The maize grains and stover yield was recorded significantly highest in treatment T₅: Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹ (53.80 and 62.44 q ha⁻¹) over all the treatments. This was followed by treatments T₂: Gypsum as per 100% GR (49.31 and 59.34), T₆: Gypsum as per 50% GR + zeolite @ 600 kg ha⁻¹ (50.26 and 59.73), T₇: Gypsum as per 100% GR + zeolite @ 300 kg ha⁻¹ (51.14 and 60.03) and T₈: Gypsum as per 50% GR + zeolite @ 300 kg ha⁻¹ (49.10 and 58.17) were statistically at par with each other but was significantly higher than other treatments for yield of maize grains and stover. The higher yields in treatment of amendments might be associated 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 gypsum. Similarly, the slight decrease in the pH of the soil due to the nitrification and acidification processes stimulated by application of fertilizers as well as by H⁺ released by roots. The addition of amendments (gypsum) had a profound influence on the exchangeable cations at all stages of crop growth. The increase in Ca, Mg and K by gypsum application with organics (FYM) due to dissolution of gypsum by the organic acid formed during decomposition of organics. This was attributed to improvement in sodicity problems by leaching Na through gypsum application which helped in better utilization of applied NPK nutrients there by increased the yields. In addition, installation of sub surface drainage in these soils directly helped in increasing the yield, by reducing water logging and removing the slats in the root zone and create favorable conditions in the root zone to take up more nutrients from the soil for optimum plant growth. The increase in yield mainly due to large quantity of salts which were harmful to crop growth have been removed and soil fertility has been increased to supply sufficient quantity of nutrients for crop growth and productivity (Basavaraja *et al.*, 2016) [13].

Table 1: Effect of amendments on nutrient uptake and yield of maize in subsurface drainage field

Treatments	Total nutrient uptake (kg ha ⁻¹)			Total micronutrient uptake (g ha ⁻¹)				Yield (q ha ⁻¹)	
	N	P	K	Fe	Mn	Zn	Cu	Grain	Stover
T1: control	62.87	7.65	46.7	830	740	487	299		
T2: 100% GR	121.78	19.42	123.82	1876	1298	1008	708	33.40	41.47
T3: 100% ES	107.37	14.65	103.39	1696	1143	706	590	49.31	59.34
T4: 100% Zeolite	96.76	12.93	98.85	1587	1020	698	554	44.50	54.57
T5: 100% GR + 100% zeolite	132.77	27.14	134.46	2034	1443	1134	805	41.95	50.24
T6: 50% GR + 100% zeolite	122.12	20.45	124.64	1888	1306	1009	716	53.80	62.44
T7: 100% GR + 50%	125.65	22.72	128.11	1907	1334	1018	728	50.26	59.73
T8: 50% GR + 50% zeolite	119.19	18.98	122.89	1870	1267	989	698	51.14	60.03
T9: 100% ES + 100% zeolite	112.51	16.32	111.87	1768	1184	765	612	49.10	58.17
T10: 50% ES + 100% zeolite	106.02	14.86	106.74	1716	1154	716	596	47.25	56.31

T1: 100% ES + 50% zeolite	110.46	15.14	110.92	1732	1176	734	607	45.78	54.36
T12: 50% ES + 50% zeolite	100.37	13.39	99.11	1656	1141	692	584	46.46	55.61
SEm(±)	2.13	1.421	1.866	43.124	34.22	39.54	14.51	44.62	53.77
CD at 5%	6.561	4.431	5.516	118.3	102.7	100.1	42.49	0.743	0.677
100% GR: Gypsum as per 100% GR	100% ES: Elemental sulphur 1/5 th of GR			100% Zeolite: Zeolite @ 600 kg ha ⁻¹					

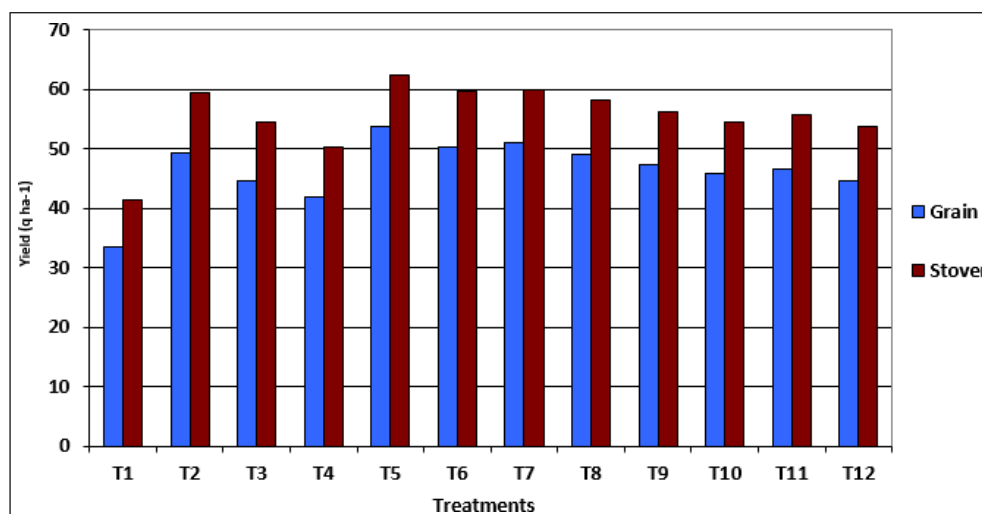


Fig 1: Effect of amendments on yield of maize in subsurface drainage field

Conclusion

The results obtained from present investigation clearly indicates the beneficial effect of combine application of gypsum with zeolite under subsurface drainage system in enhancing the nutrient uptake and yield of maize in a sodic soil, when compared to either sole application of amendments sources and combine application of elemental sulphur with zeolite. The biomass production in maize crop grown in sodic soils under SSD field in terms of their fresh and dry matter yield, mainly depends on uptake of nutrient and micronutrient by maize crop which showed highest with application of Gypsum as per 100% GR + zeolite @ 600 kg ha⁻¹. The present investigation was based on one season experimentation it needs to be verified by applying the inorganic amendments in combinations along with proper drainage system (sub surface drainage system) for better results.

Acknowledgement

I am very thankful to Department of Soil Science and Agricultural Chemistry, PGI, MPKV, Rahuri for providing all facilities required during course of study and also would like to thank my research guide, colleagues for their good counsel and continued encouragements during the course of study.

References

- Murdia LK, Wadhvani R, Wadhawan N, Bajpai P, Shekhawat S. Maize Utilization in India: An Overview American Journal of Food and Nutrition. 2016; 4(6):169-176.
- Anonymous. Agricultural Statistics at a Glance 2018, Ministry of Agriculture and Farmers Welfare (Department of Agriculture, Cooperation and Farmers Welfare; Directorate of Economics and Statistics) Govt. of India, 2019.
- Kumar R, Srinivas K, Boiroju N, Gedam P. Production performance of maize in India: approaching an Inflection point International Journal of Agricultural and Statistical Science. 2014; 10(1):241-248.
- Mandal AK, Sharma RC, Singh G, Dagar JC. Computerised database on Salt affected Soils in India. Technical Bulletin, ICAR Central Soil Salinity Research Institute, Karnal, Haryana, India, 2010.
- Goel A, Tiwari P. An overview of impact of subsurface drainage project studies on salinity management in developing countries. Applied Water Science, 2015. DOI 10.1007/s13201-015-0329-4.
- Padalkar RC, Jadhav PL, Jadhav AS, Raut PD. Use of subsurface drainage treatment for reclamation of saline soil: A case study of Kasabe Digraj village, District: Sangali, State: Maharashtra. Proceeding of International Conference SWRDM, 2012, 269-280.
- Richards LA. Diagnosis and Improvement of saline and alkaline soils. Agricultural Handbook No. 60, United Soil Salinity Laboratory Staff, Oxford and IBH Publ. Co. Calcutta, 1968, 1-156.
- Parkinson JA, Allen SE. A wet oxidation procedure suitable for the determination of nitrogen and other mineral nutrients in biological material. Communication in Soil Science and Plant Analysis. 1975; 6:1-11.
- Jackson ML. Soil Chemical Analysis. Prentice Hall Pvt. Ltd., New Delhi, 1973, 69-182.
- Chapman HD, Pratt PF. Methods of analysis for soil, plant and water. Division of Agricultural Science, California University, USA, 1961, 309.
- Zososki RJ, Burau RG. A rapid nitric perchloric acid digestion method for multi element tissue analysis. Communications in Soil Science and Plant Analysis. 1977; 8:425-436.

12. Jadhao SM. Assessment of Saline-Sodic Swell-Shrink Soil during Reclamation Process, MPKV, Rahuri. *Ph.D. Thesis* submitted to the Mahatma Phule Krishi Vidyapeeth, Rahuri (MS) India, 2003.
13. Basavaraja PK, Yogendra ND, Mohamed SH, Nalina CN. Importance of Sub Surface Drainage in Amelioration of Salt Affected Soils and Enhancing Crop Productivity. *Indian Journal of Ecology*. 2016;43(1):58-64.
14. Asif M, Nadeem MA, Aziz A, Safdar ME, Adnan M, Ali A, Ullah N, Akhtar N, Abbas B. Mulching improves weeds management, soil carbon and productivity of spring planted maize (*Zea mays* L.). *International Journal of Botany Studies*. 2020;5(2):57-61.