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Study on Salinity Reduction and Changes in Chemical Properties in Saline Soil

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ABSTRACT

Background: The aim of the work was to evaluate the effects of different treatments viz manure as organic amendments, gypsum as amendments and nitrogen resources on salinity of saline soil.

Methods: The research was conducted using a 2×4×3 factorial design. The first factor was manure (non-manure and manure), the second factor was the addition of gypsum, @ 0, 0.75, 1.5 and 3.0 ton ha^{-1}) and third factor was source of nitrogen *i.e.* without N, nitrate and ammonium fertilizer. These three factors were repeated 3 times. Data were analyzed using one-way analysis of variance followed by the Duncan multiple range test for comparisons among means with a significance level of 5%.

Result: This research markedly reduced pH, EC, Na and markedly increased sulfate, K content. But CEC, SAR, ESP, total N, nitrate, ammonium were not significant. The highest Ca content was in the 1.5 tons ha^{-1} gypsum treatment and non manure. Meanwhile, in the interaction between gypsum and N resources, the highest Mg content was 3 tons ha^{-1} of gypsum and nitrate.

Key words: Electrical conductivity, Exchangeable sodium percentage, EC, Gypsum, Manure, Na, Nitrogen resource, Saline soil.

INTRODUCTION

Soil salinity is a common abiotic stress that changes the geographical distribution of plants. Salinity impacts are most serious in countries where all or most of the agricultural production is based on irrigation. As irrigated agriculture develops, more salinity problems will develop as there are millions of hectares of potentially irrigable land that could become salty (Kibria and Hoque, 2019). Saline soils are generally defined as saline soils having an exchangeable sodium percentage of less than 15 per cent and a sodium adsorption ratio of less than 13 per cent. Readings indicating saline soils include an electrical conductivity result greater than 4 ds m^{-1} and a pH level of less than 8.5. Sodic soils must have an electrical conductivity reading of less than 4 ds m^{-1}, similar to normal soils. However, other results will be abnormal. The results will show a percentage of exchangeable sodium greater than 15 per cent and a sodium adsorption ratio greater than 13 per cent. The soil will also have poor structure and will be very alkaline with a pH reading of 8.5 or more (Shrivastava and Kumar 2015; Lingappa and Kuligod 2017; Purbajanti *et al*., 2019). Moreover, saline water is used for irrigation in some regions, which increases the salt contents in topsoil. In this regard, gypsum has been reported several times to maintain optimal K^+/Na^+ and Ca^{2+}/Na^+ ratios, lower pH and provide plants with nutrient sulphur (S) needed in saline soils (Ahmed *et al*., 2016). Through the administration of S, gypsum increases plant tolerance and resistance to biotic and abiotic stress factors by assisting protein synthesis, compounds containing chlorophyll and increasing P and N uptake. In addition, the combined use of organic matter (*e.g.*, compost and manure) as a bio-organic amendment with gypsum has great potential in improving saline soils (Bello *et al*., 2021).

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The aim of the work was to evaluate the effects of different manure as organic amendments, gypsum as amendments and nitrogen resources on soil salinity of saline soil. The information obtained from this study will help provide guidance on the selection of manure as organic amendments, gypsum as amendments and nitrogen resources in ameliorating coastal saline soil while considering their environmental concerns.

MATERIALS AND METHODS

Location and soil sampling

The study was conducted in April-September 2017 in saline soil, Jepara, Central Java, Indonesia. The land is planted with forage namely Panicum maxium. Plain with 0-25 m elevation, located on 110°5′-110°6′ of East Longitude and between 5°43′-6°47′ South Latitude. The research was conducted using a 2×4×3 factorial design. The first factor was manure (non-manure and manure), the second factor was the addition of gypsum, namely without gypsum,

gypsum @ 0.75 ton.ha^{-1}, gypsum @ 1.5 ton ha^{-1} and gypsum @ 3 tons ha^{-1}, after the application is irrigated. The third factor is the source of N, namely without N, nitrate source (KNO_3) and ammonium source $(NH_4)_2 SO_4$. These three factors were repeated 3 times.

Data collection and collection procedures

The results of the initial soil analysis (before treatment) are as follows; 49.5% clay (below 0.002 mm), 31.68% silt (0.02-0.002 mm) and 19.17% sand (2.00-0.02 mm) which belonged to the clayey texture class. The pH value of the experimental soil was 8.3, which was high. Very high electrical conductivity (19.6 mmhos cm^{-1}), organic matter is 3.0%, low total N (0.12%), low Cl (13.3 ppm), low SO_4 (0.2 ppm), low available K (0.33 Cmol (p^+) kg^{-1}), available Ca is very low [1.81 Cmol (p^+) kg^{-1}], CEC is high [28.2 cmol (p^+] kg^{-1}), available Na is very high (2.08 Cmol (p^+) kg^{-1}), available Mg is low (0.49 Cmol (p^+) kg^{-1}). The SAR and ESP values were calculated based on formula given in (Abdel-Fattah, 2012). the experimental soil had a SAR value of 1.9 and an ESP of 7.4. The research variables were texture (wet sieve method), acidity (1:5) (pH meter), EC (1:5, conductometer), Organic meter (Walkey and Black), total Nitrogen (Kjeldahl), NO_3 (Morgan Wolf, Spectrophotometer), NH_4 (Morgan Wolf, Spectrophotometer), CEC (ammonium acetate, Kjeldahl), Na, Ca, Mg, K (ammonium acetate, AAS), anions (Na acetate).

Data analysis

Data were analyzed using one-way analysis of variance followed by the Duncan multiple range test (Dong, 2012) for comparisons among means with a significance level of 5%.

RESULTS AND DISCUSSION

Soil Physico-chemical properties

The highest EC in the control was 19.6 mmhos cm^{-1} and the lowest EC (5.4 mmhos cm^{-1}) was achieved by the application of manure @20 ton ha^{-1} gypsum @ 3 ton ha^{-1} ammonium (Table 1). Based on the above reaction Ca^{++} will expel Na^+ which then Na_2SO_4 and other soluble salts is leached during regularly wasting so that there is a decrease in Na which is then able to reduce soil EC. The amount of dissolved salt depends on the relative amount of soil and water used so various interpretations of the EC value arise because the effect of salinity changes depending on various factors such as irrigation water, soil texture, salt type, plant growth status, drainage and climate (Tan and Thanh 2021).

The application of manure together with gypsum allows a decrease in pH because the manure contains organic acids that provide H^+ ions into the soil and gypsum contains sulfate ions so that it can lower the soil pH. Sulfate ion functions as an anion that can lower soil pH. The decrease in soil pH due to gypsum application is in accordance with

Table 1: Manure, gypsum and nitrogen sources on physiochemical properties of soils.

Manureton.ha^{-1}	Gypsum ton.ha^{-1}	N resources	EC (mmhos cm^{-1})	pH	CEC me.100 g^{-1}	SAR	ESP
0	0	Non N	19.6^{a}	8.3^{a}	28.2	1.9	7.4
		Nitrate	14.3^{a}	7.2^{cd}	21.0	1.3	9.9
		Ammonium	14.4^{a}	7.2^{cd}	22.3	1.2	9.5
	0.75	Non N	12.9^{b}	7.3^{ab}	22.7	1.0	8.6
		Nitrate	11.9^{bc}	7.4^{a}	24.1	1.4	8.9
		Ammonium	11.9^{bc}	7.3^{ab}	24.5	1.1	8.4
	1.5	Non N	10.3^{d}	7.4^{a}	24.0	0.9	7.8
		Nitrate	10.4^{d}	7.3^{ab}	22.5	0.8	7.9
		Ammonium	10.4^{d}	7.2^{cd}	24.2	1.3	8.8
	3	Non N	9.1^{e}	7.3^{ab}	25.4	1.2	8.0
		Nitrate	9.1^{e}	7.2^{cd}	27.1	1.2	7.5
		Ammonium	9.1^{e}	7.3^{ab}	27.0	1.0	7.0
20	0	Non N	10.3^{a}	7.4^{a}	23.6	1.1	7.6
		Nitrate	11.2^{bc}	7.2^{cd}	23.2	1.1	9.3
		Ammonium	11.6^{bc}	7.3^{ab}	22.9	1.1	9.2
	0.75	Non N	8.9^{e}	7.4^{a}	22.7	1.0	8.2
		Nitrate	7.5^{f}	7.3^{ab}	24.1	1.2	8.0
		Ammonium	7.1^{fg}	7.2^{cd}	24.5	1.2	7.9
	1.5	Non N	7.6^{f}	7.2^{cd}	24.0	1.1	7.5
		Nitrate	6.0^{gh}	7.3^{ab}	22.5	1.0	6.8
		Ammonium	6.5^{fgh}	7.3^{ab}	24.2	1.0	6.2
	3	Non N	5.8^{h}	7.1^{e}	25.3	0.9	6.2
		Nitrate	5.8^{h}	6.8^{f}	28.7	0.9	6.1
		Ammonium	5.4^{h}	6.9^{f}	29.1	0.9	6.2

Note: numbers followed by the same letter show that they are not significantly different on the DMRT 0.05 test.

Bello *et al*., (2021) that gypsum is used to neutralize soil with a high sodium and/or salt content so that it can reduce soil pH. Shehzad *et al*.,(2020) described that continuously adding farmyard manure to saline soil results in a reduction of soil pH and enhancement in carbon content along with exchange capacity of replaceable cations. The results of the study are in accordance with Abdel-Fattah (2012) who reported that gypsum was used for sodic soil amendment and reclamation of salt irrigated soil structures by reducing CO_3^{2-} and OH^-. According to Dong, (2012) there was a change in soil fertility in saline soils that underwent reclamation (improvement), namely soil fertility was getting better, a decrease in salinity and changes in groundwater salinity.

The application of Manure, gypsum and nitrogen fertilizers in the form of ammonium or nitrate did not significantly reduce the SAR values. Based on Sabareshwari and Ramya. (2018): Yuvaraj *et al*., 2021), SAR is used to estimate water quality, namely the concentration of Na, Ca and Mg ions in one liter of solution. According to Brusseau *et al*., (2019) if the SAR value is less than 10, this means that the water can be used for irrigation because it has low sodium content. The application of manure, gypsum and nitrogen fertilizers in the form of ammonium or nitrate did not significantly influence the ESP values. Factors that affect the dissolution of gypsum are soil solution, temperature, water flow, gypsum grain size and soil Na saturation (Singh, 2016).

Total N, Nitrate, ammonium and sulfate soil content

Based on Table 2, it is known that the application of 20 tons. ha^{-1} manure, gypsum and nitrogen source was not significant effect on total soil N. The application of 20 tons. ha^{-1} manure, gypsum and nitrogen source statistically was not significant effect on soil nitrate. Soil ammonium content was not significant effect with applied manure, gypsum and nitrogen source. Organic fertilizers with disadvantages such as low nutrient content, slow decomposition and varied nutrient composition have many benefits including balanced nutrient supply, increased nutrient availability, increased microbial activity, decomposition of toxic elements, improved soil structure and availability of groundwater (Bhuyan *et al*., 2021).

The nitrogen sources in the form of nitrate and ammonium increased the sulfate content of the soil compared to those without nitrogen but the nitrogen form gave the same effect (Table 2). The highest soil sulfate content was in the treatment combination between manure-gypsum 3 tons ha^{-1} and ammonium (44.5 ppm) and the lowest was in the treatment combination without manure, without gypsum and without nitrogen (0.20 ppm). The increase in the sulfate content of the soil was due to the addition of element sulphur (S) derived from manure and the decomposition of gypsum applied to the soil. Based on Sajal and Nasrin (2020). there was a change in soil fertility

Table 2: Content of soil nitrogen, nitrate, ammonium and sulfate.

Manuretons. Ha^{-1}	Gypsumtons.Ha^{-1}	N Source	N total (%)	Nitrate (ppm)	Ammonium (ppm)	Sulfate (ppm)
0	0	Non N	0.12	6.8	10.9	0.20 ^{f}
		Nitrate	0.10	219.4	14.6	19.9 ^{e}
		Ammonium	0.13	7.5	38.6	22.1 ^{e}
	0.75	Non N	0.17	7.3	17.1	20.2 ^{e}
		Nitrate	0.14	262.7	23.0	22.2 ^{e}
		Ammonium	0.14	7.6	27.5	22.5 ^{e}
	1.5	Non N	0.16	7.2	18.9	21.6 ^{e}
		Nitrate	0.16	266.1	23.6	29.2 ^{d}
		Ammonium	0.16	8.6	138.5	29.0 ^{d}
	3	Non N	0.15	8.0	24.0	29.1 ^{d}
		Nitrate	0.18	279.6	24.1	29.0 ^{d}
		Ammonium	0.17	15.4	159.7	32.6 ^{cd}
20	0	Non N	0.12	20.5	18.1	20.4^{e}
		Nitrate	0.13	280.5	31.8	34.3^{bcd}
		Ammonium	0.14	18.3	98.6	32.2^{bcd}
	0.75	Non N	0.17	19.8	23.0	36.7^{bc}
		Nitrate	0.17	335.4	29.8	34.3^{cd}
		Ammonium	0.20	19.7	186.2	32.2^{cd}
	1.5	Non N	0.20	21.7	20.6	32.1^{cd}
		Nitrate	0.20	319.6	37.6	34.1^{cd}
		Ammonium	0.22	31.5	182.5	33.9^{cd}
	3	Non N	0.21	26.4	28.4	36.6^{bc}
		Nitrate	0.26	313.6	37.9	41.1^{ab}
		Ammonium	0.26	40.3	150.2	44.5^{a}

Note: Numbers followed by the same letter show that they are not significantly different on the DMRT 0.05 test.

in saline soils that underwent reclamation (improvement), namely soil fertility was getting better, a decrease in salinity and changes in groundwater saline. Both ammonium and nitrate form can be utilized by plants (Zhu *et al*., 2020).

Soil potassium, sodium, calcium and magnesium content

The research results of Saleque *et al*., (2010) in saline soils, the exchangeable potassium content at Munshiganj, Ashasuni and Patharghata was in the range of 0.94-2.49, 0.32-0.53 and 0.25-0.30 cmol.kg^{-1}.

The K content is affected by the interaction between manure, gypsum and N sources (Fig 1a and Fig 1b). In non-manure, N sources, both nitrate, ammonium and non-N, show an increase in K content, as well as the use of manure has the same pattern, where the highest is in 3 tons ha^{-1} gypsum, nitrate in both non-manure or with the addition of manure. available nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}) and potassium (kg ha^{-1}) may be due to an increase in levels of organic and inorganic fertilizers (Meena *et al*., 2016).

The resulting Na content is affected by the interaction between manure and gypsum (Fig 2a), also affected by the interaction between gypsum and N sources. In Fig 2a. It can be seen that the lowest yields were gypsum 3 tons ha^{-1} and manure 3 tons ha^{-1} which were significantly different from all treatments. In Fig 2b, the lowest yield is seen in gypsum 1.5 ton ha^{-1} and nitrate. One of the deleterious effects of high salinity stress is manifested as nutrient imbalances like high soil Na+ concentrations reduce the amounts of available K^+ , Mg^{++} and Ca^{++} for plants resulting in Na+ toxicity on one hand and deficiencies of essential cations on the other (Soni *et al*., 2022).

Soil Ca content due to the interaction of manure and gypsum is presented in Fig 3a. Meanwhile, the soil Ca content due to the interaction of gypsum and N sources is presented in Fig 3b. The highest Ca content was in the 1.5 tons ha^{-1} gypsum treatment and non manure. As for the interaction between gypsum and N sources, the highest Ca value was in the gypsum and non-N treatment. This could be due to an increase in the level of applied gypsum as well as Ca_2+, a replacement of the soil exchange complex that produces Na+, which is triggered by leaching of salt away from the root zone. (Rana *et al*., 2018). In order to understand these mechanisms, researchers have focused on ion accumulations and transfers, especially Na^+, K^+ and Ca^{+2} that appear in plant organelles under salt stress (Gulmezoglu *et al*., 2016).

The Mg content of soil due to the influence of manure and gypsum can be seen in Fig 4a and due to the influence of gypsum and N resources can be seen in FIg 4b. the highest Mg content was in non manure and 1.5 tons ha^{-1}

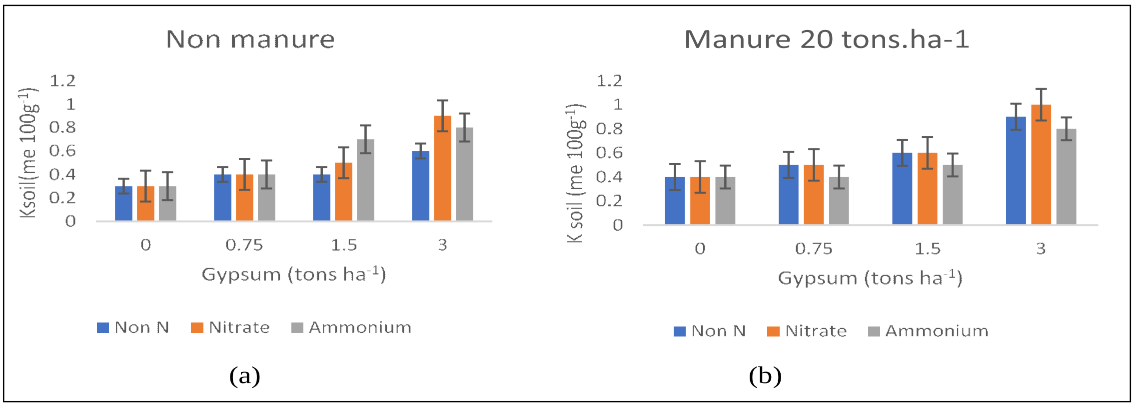

Fig 1: Effect of manure, gypsum and N resources on soil potassium content.

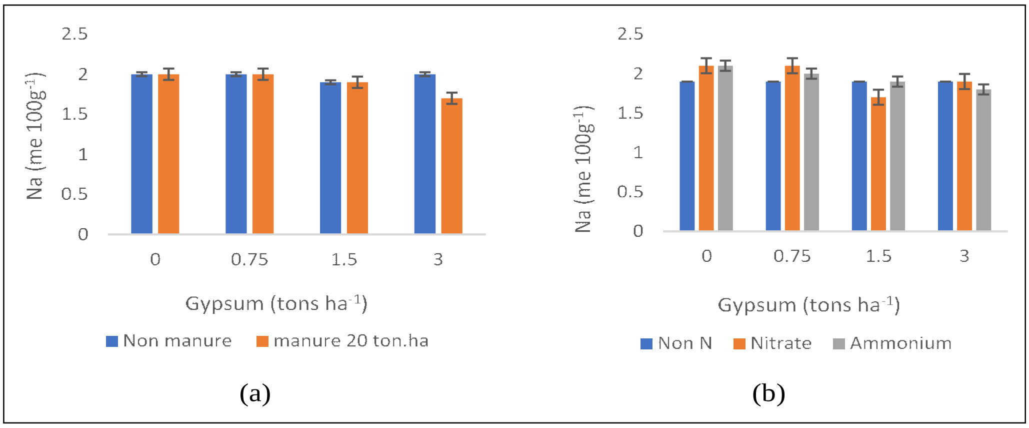

Fig 2: Content of Na in the soil: (a) effect of manure and gypsum (b) effect of gypsum and N resources.

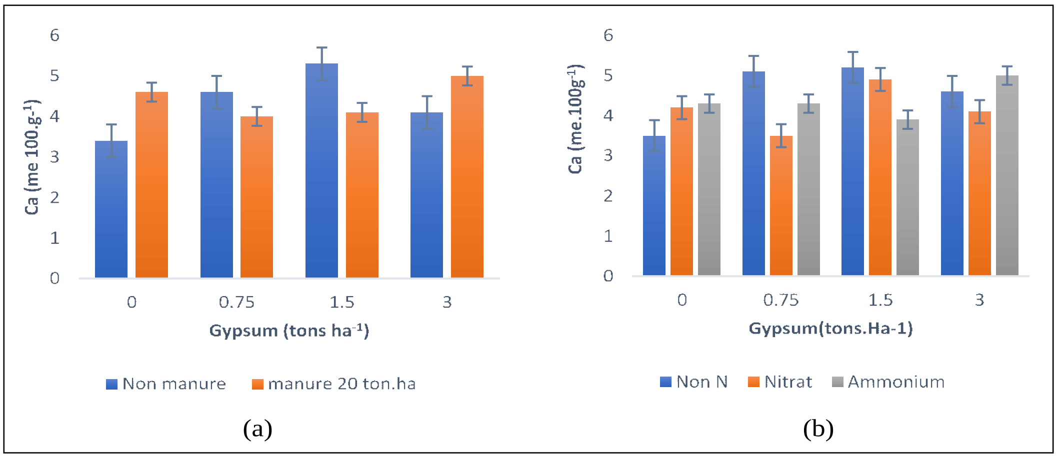

Fig 3: soil calcium content: (a) effect of application manure and gypsum (b) effect of application gypsum and N resources.

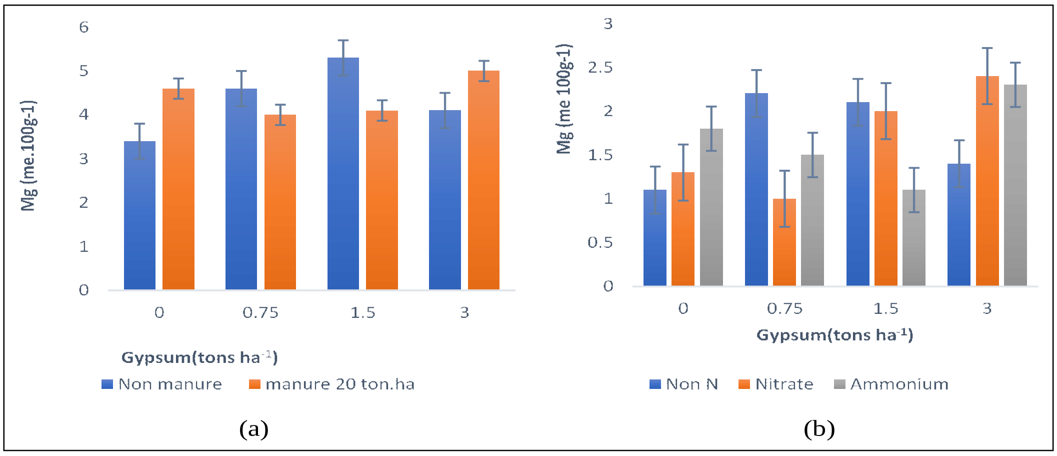

Fig 4: Soil magnesium content: (a) effect of application manure and gypsum(b) effect of application gypsum and N resources.

gypsum administration. Meanwhile, in the interaction between gypsum and N resources, the highest Mg content was 3 tons ha^{-1} of gypsum and nitrate. This is in accordance with Rana *et al*., (2018) that Gypsum has proven to be an economical and better amendment for saline-sodic soil reclamation due to its universal availability, low cost and luxurious supply of Ca_2+. Higher than permissible NO_3- levels in leachate recorded with the application of gypsum accompanied by N above the recommended level. This may be because the application of gypsum increases soil permeability and reduces deflocculation, thereby increasing the percolation of water carrying dissolved NO3.

CONCLUSION

This research markedly reduced pH, EC, Na and markedly increased sulfate. But CEC, SAR, ESP, total N, nitrate, ammonium were not significant. The highest K content is nitrate in gypsum 3 tons ha^{-1} for both non-manure and manure. The highest Ca content was in the 1.5 tons ha^{-1} gypsum treatment and non manure. Meanwhile, in the interaction between gypsum and N resources, the highest Mg content was 3 tons ha^{-1} of gypsum and nitrate.

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