RESPONSE OF TWO VARIETIES OF MAIZE TO APPLICATION OF AMELIORANTS IN SALINE SOIL †

[RESPUESTA DE DOS VARIEDADES DE MAÍZ A LA APLICACIÓN DE ENMIENDAS EN SUELOS SALINOS]

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SUMMARY

Background. Salinity cause reducing the growth and yield of crops. The application of ameliorants was an alternative to reduce salinity stress and increasing the growth and yield of crops. **Objective**. To evaluate the response of maize crops with ameliorants application on saline soil. **Methodology**. The research was conducted in Sidomukti Village District, Brondong Lamongan. The research used split-plot designs with main plots were varieties (P-21 and Bisma) and subplots were ameliorant types (without ameliorant, cow manure, gypsum, Sunhemp (*Crotalaria juncea*) and rice straw). **Results**. The application of ameliorants at saline soil reducing salinity stress with increasing the growth and yield of maize. Gypsum and cow manure were appropriate to increase growth and yield of both maize varieties P-21 and Bisma. Gypsum and cow were also increasing the content of Nitrogen, Phosphorus and Potassium of plants, as well as reducing the content of proline, Na and Cl shoot root ratio. **Implications**. Crops production in saline soil can use ameliorants e.g. cow manure and gypsum. **Conclusion**. The use of ameliorants such as gypsum or cow manure can increase maize growth and yield in saline soil.
Key words: ameliorant; maize; growth; proline; saline; Cl shoot/root.

RESUMEN

Antecedentes. La salinidad provoca la reducción del crecimiento y rendimiento de los cultivos. La aplicación de un enmienda fue una alternativa para reducir el estrés salino y aumentar el crecimiento y rendimiento de los cultivos. **Objetivo.** Evaluar la respuesta de los cultivos de maíz la aplicación de enmienda en suelos salinos. **Metodología.** La investigación se llevó a cabo en el distrito de la aldea de Sidomukti, Brondong Lamongan. La investigación utilizó diseños de parcelas divididas con parcelas principales fueron variedades (P-21 y Bisma) y subparcelas fueron de tipos enmienda (sin enmienda, abono de vaca, yeso, *Crotalaria juncea*, y paja de arroz). **Resultados.** La aplicación de enmienda en suelos salinos reduciendo el estrés de salinidad, mejora el crecimiento y rendimiento del maíz. El yeso y el abono de vaca fueron apropiados para aumentar el crecimiento y el rendimiento de las variedades de maíz P-21 y Bisma. El yeso y la el abono de vaca también aumentaron el contenido de Nitrógeno, Fósforo y Potasio de la planta, además de reducir el contenido de prolina, Na y la proporción de Cl en los brotes de las raíces. **Implicaciones.** La producción de cultivos en suelo salino puede utilizar un enmienda, p. ej. abono de vaca y yeso. **Conclusión**. El uso de enmienda como yeso y abono de vaca puede aumentar el crecimiento y el rendimiento del maíz en suelos salinos.
Palabras clave: Cl /raíz; maíz; K / Na; prolina; salino.

INTRODUCTION

Salinity becomes agricultural problems. It causes salinity stress, reducing the growth and yield of plant. The high salinity value shows the influence of salinity (Na) is high, where the value of EC (Electrical Conductivity) also increased. Soil belongs to saline soil when it is content of EC reaches 4 dS m^{-1} and has 15 % exchangeable sodium (Shrivastaka and Kumar, 2015). Generally, high salinity has a double effect on growth, which reduces water potential on the crops caused by increasing the potential osmotic on rooting media, and gives the toxic effects due to high concentration of ions Na^+ and Cl^- accumulated in plant tissues. Due in the short term Na^+ and Cl^- has inhibited plants growth caused by water shortage response roots. The effects in the long term that the plants will suffer a reduction leaves so disrupted the process of photosynthesis and plant growth can be inhibited (Aini *et al*., 2014).

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An alternative to increasing nutrient availability, improving the fertility of the physical, chemical and biological of soil salinity can use an ameliorant (a material to improve the soil) such as organic manure (e.g. cow manure, green manure), green manure or straw (Horneck *et al*., 2007). Compost of rice straw reduced soil salinity through increasing Ca^{2+}, K^{+}, organic matter capacity exchange cation (CEC) and water holding capacity (Mahmoud *et al.,* 2009). Application rice straw, green manure, cow/chicken manure increase plant growth, yield, nutrient uptake and decrease soil pH (Zhao *et al*., 2014; Awad *et al.,* 2015; Akter *et al.*, 2018). The application of Sunhemp (*Crotalaria juncea* L.) as green manure is a rapid growth rate and it can produce much forage. Sunhemp is high quality green manure, with content carbon 407 g kg^{-1}, nitrogen 33.4 g kg^{-1}, lignin 47.8 g kg^{-1}, polyphenols 22.2 g kg^{-1} and 12.2 C/N ratio in the leaf (Fonte *et al*., 2009). Islam *et al*. (2015) reported that Sunhemp used as green manure was able to improve growth, nitrogen uptake and protein content on grain and straw of rice. Sunhemp age of 3 weeks after planting has content of nitrogen higher than 4 and 5 weeks cause content less of lignin in the plant tissue.

Gypsum ($CaSO_4.2H_2O$) also decreased levels of Na^{+} because the element of Ca^{2+} from gypsum can replace Na^{+} and enable to leach which causes decreased pH in soil saline and increasing nutrient use efficiency (Ali and Kahlown, 2001; Horneck *et al*., 2007) and increasing yield maize, sorghum, luacaena (Chen and Dick, 2011) and rice in saline soil (Helmy *et al.,* 2013). The applications of ameliorants to improve the growth and yield in is a lot, but research on the application of organic ameliorant and gypsum on saline soils in Indonesia is still limited. The research objective was to study the response of maize plants with application types of ameliorant on saline soil.

MATERIALS AND METHODS

The research was conducted on saline land with a value of EC ± 4,24 dSm^{-1} in Sidomukti Village, District Brondong, Lamongan located at 6° 54'43.5 "S 112° 11'48.4 "E with the altitude of 25 m above sea level. Soil type was Grumosol soil with pH of 8.6, C-organic 2.12%, Nitrogen total 0.2%, Phosphorus 13 ppm, Potassium 3.79 me 100 g^{-1}, Sodium 5,93 me 100g^{-1}, Calcium 42, 25 me 100 g^{-1} and Magnesium me 100 11.95 g^{-1}. The research was conducted from May until October 2016. The research used Split Plot Designs with three replication. The main plots consisted of the varieties (P-21 and Bisma) and the subplot consisted of the types ameliorants: without ameliorant, cow manure 20 t ha^{-1} (Choudhary *et al*., 2004), gypsum 5 t ha^{-1} (Cha-um *et al.,* 2011), Sunhemp (*Crotalaria juncea*) 20 t ha^{-1} (Choudhary *et al*., 2004) and rice straw 5 t ha^{-1} (Pang *et al*., 2010).

Land preparation began with land clearing and weeding using mixed herbicides containing the active ingredient of Paraquat dichloride and dimethyl 2,4-D amine which each concentration was 297 g/L and 825 g/L. The dosage used was 450 ml mixture of herbicide active ingredient herbicide Paraquat dichloride and 30 ml of dimethyl amine herbicide active ingredient mixed with 14 liters of water. After 2 weeks of herbicide application, and tillage subsequently made beds measuring 5x5 m. Application of cow manure and gypsum were made by mixing in accordance with the treatment plots. Sunhemp applied ± 3 weeks after sowing (Islam *et al.* (2015), which applied by shredded and mixed into the soil in fresh condition. Application of rice straw was chopping with coarse and mixed in a plot of land according to the treatment.

Cow manure, rice straw and sunhemp were applied two weeks before planting while gypsum was one week before planting. Insecticide with the active ingredient dimetomorf 50% was applied to maize seeds at a dose of 10 grams mixed with 1 kg of maize seed to prevent downy mildew attack. Planting was done by making the planting hole which Space was 75x30 cm and filled by two seeds of each hole, so the population of one bed was 119 plants.

Fertilizer used was Compound Fertilizer (24-10-12) at a dose of 830 kg ha^{-1}. Fertilization was done at 7, 21 and 45 days after planting. Irrigation schedule was once two weeks at 2 to 6 weeks after planting and continuing once two days on 8 weeks after planting until harvesting. Applications PGPR conducted on 24, 35, 40 and 52 days after planting by drenching the soil around each plant with 30 ml PGPR with concentration 22.5 ml l^{-1}.

Data on maize growth was recorded, including leaf area, root dry weight and shoot dry weight on 10 weeks after planting, while data on maize yield ware recorded by measuring dry seed per plant 14 week after planting. Plant analysis consists of nutrient content in leaf such as total nitrogen, phosphorous, potassium, sodium and Cl shoot root ratio and analysis of proline content. The data were statistically analyzed by ANOVA using the

GenStat 18th Edition. The treatments were compared with the Least Significant Differences (LSD) test at 0.05 level.

RESULT AND DISCUSSION

Application types of ameliorant have different responses in two varieties in leaf area, root dry weight, shoot dry weight and grain weight (Figure 1A, 1B, 1C and 1D). Generally, application of ameliorant can increase plant growth and yield of maize varieties in saline soil. The results of this research were similar with Patel and Saraf, 2013; Zhao *et al*., 2014; Li-Ping *et al*., 2015. The application of gypsum on P-21 variety, significantly increasing leaf area, shoot dry weight and grain weight. Such as responses of root dry weight, application of cow manure and gypsum significantly increasing root dry weight. On Bisma Variety, applications of cow manure, gypsum and rice straw increased leaf area, root dry weight, shoot dry weight and grain weight than without ameliorant. Application of gypsum in P-21 and Bisma variety increase grain weight per plant as 57.26% and 58.92% compared without ameliorant.

The plant was grown under salinity stress would produce secondary metabolism such as proline (Oyetunji and Francis, 2014). Proline accumulation was the defense response of the stressed plants due to osmotic pressure in the cell (Cha-um and Kirdmanee 2009). The content of proline was influenced by the varieties and types of ameliorant (Figure 2A). Application of ameliorant on P-21 variety significantly decreases proline content the plant, while on Bisma variety, application cow

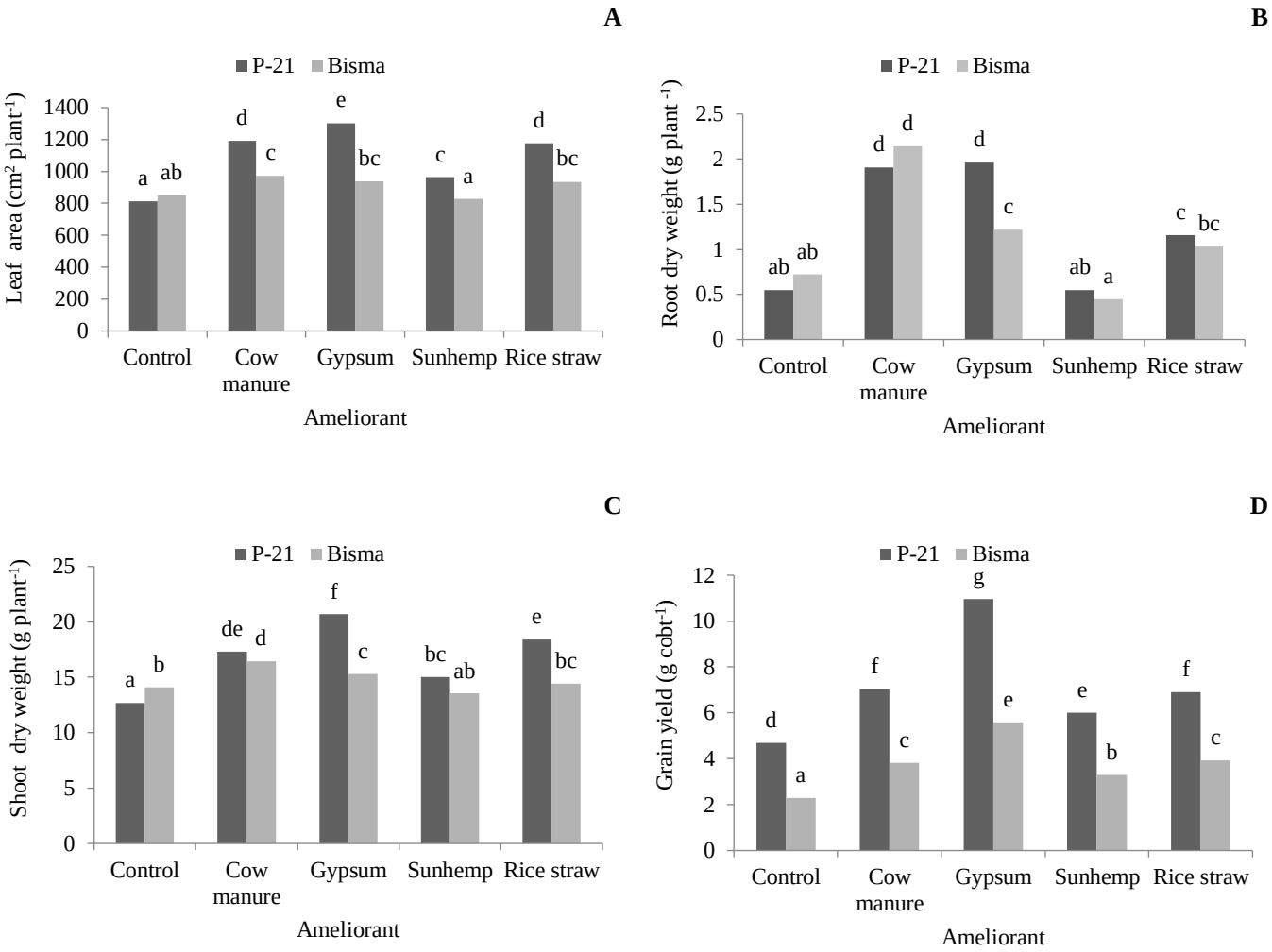

Figure 1. Response of leaf area leaf area (A), root dry weight (B), shoot dry weight (C), grain yield (D) of two maize varieties due to application of different ameliorant types.

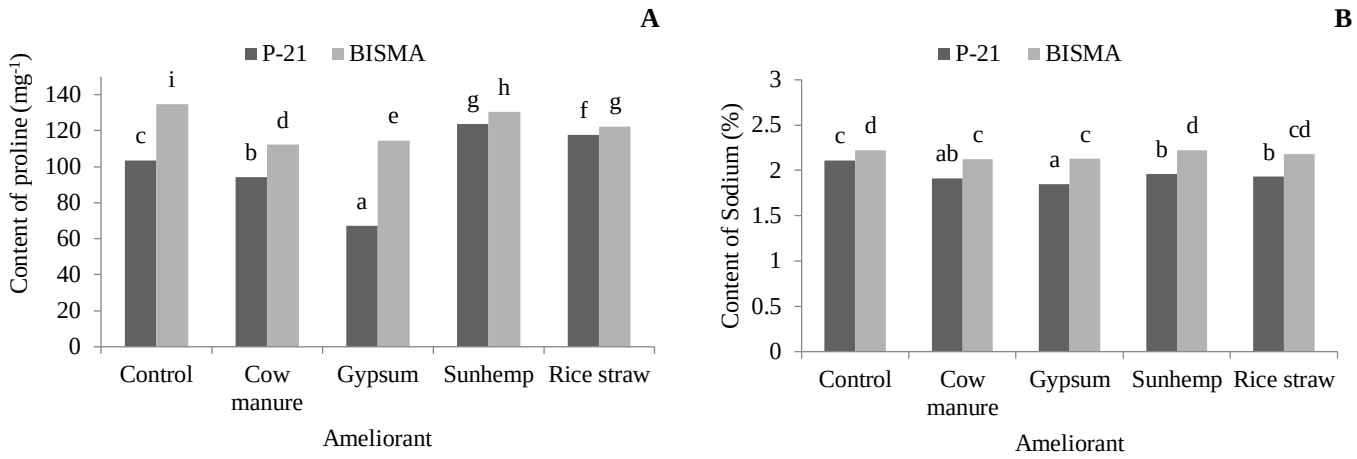

Figure 2. Content of Proline (A) and Sodium (B) due to application of ameliorant types in two maize varieties.

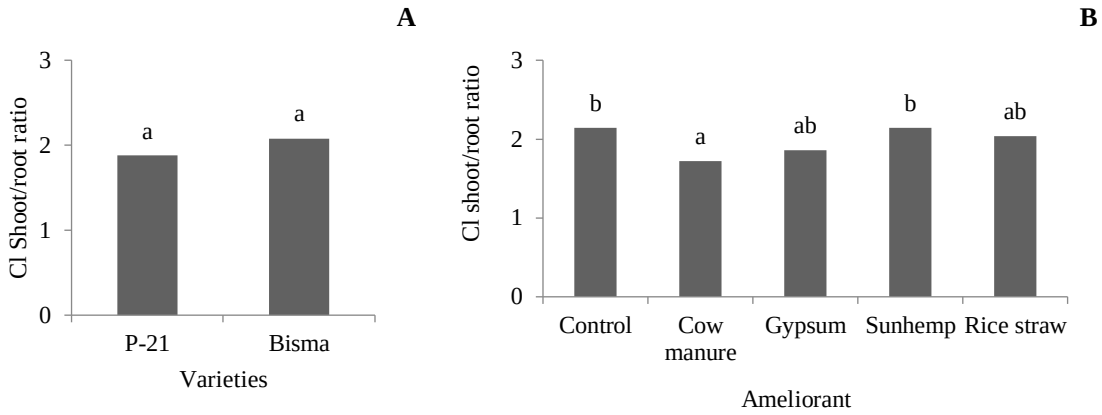

Figure 3. Cl shoot /root ratio in two maize varieties (A) due to application of ameliorant types (B).

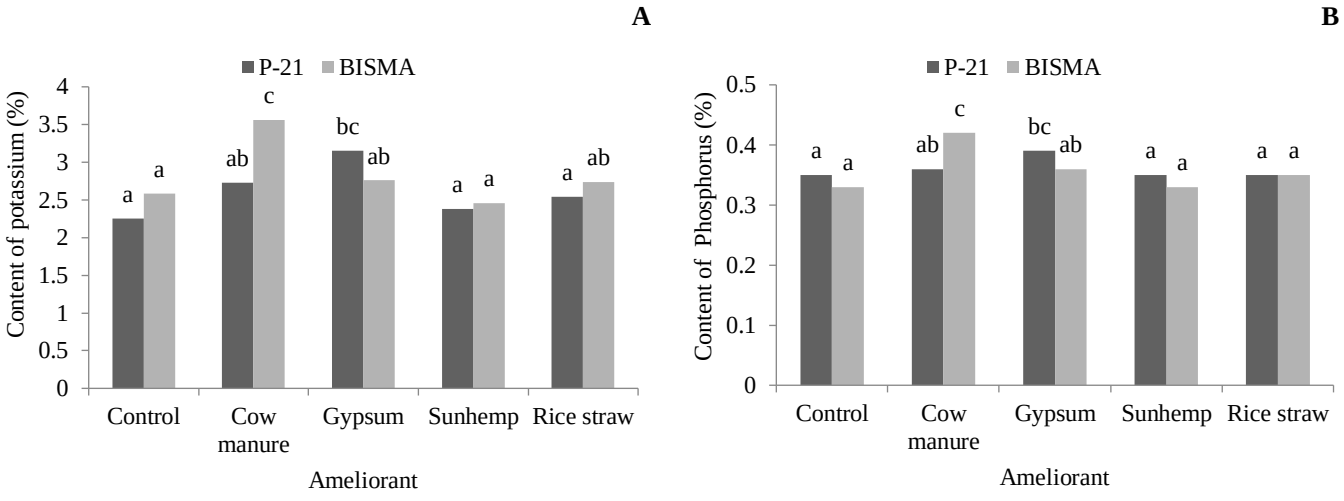

Figure 4. Content of Potassium (A) and Phosphorus (B) due to application of ameliorant types in two maize varieties.

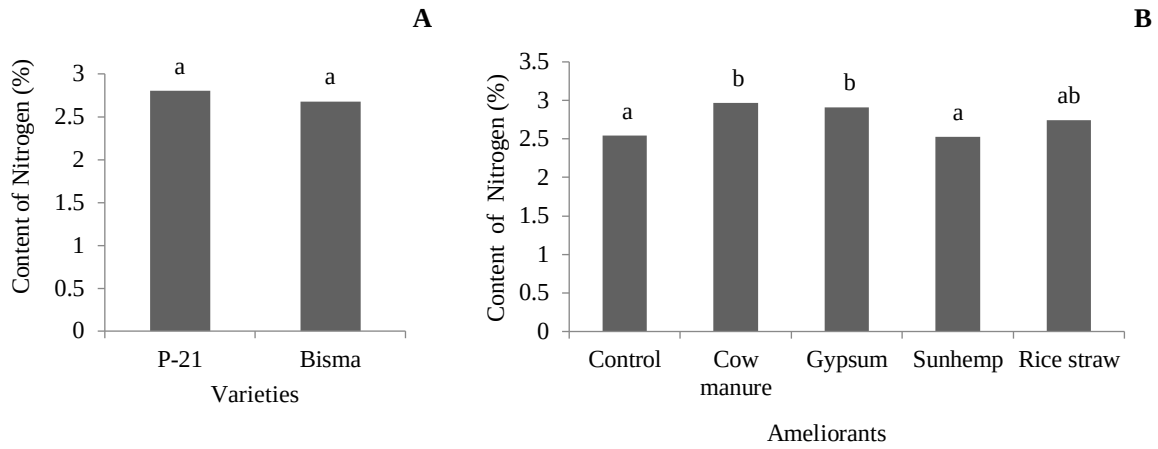

Figure 5. Content of Nitrogen in two maize varieties (A) due to application of ameliorant types (B).

manure and gypsum more effectively decrease proline content than without ameliorant, sunhemp and rice straw. Application of ameliorant significantly decreases the content of sodium in shoot dry weight of two maize varieties, similar to the result of research (Yamika *et al*., 2018). The content of sodium was influenced by the varieties and types of ameliorant (Figure 2B). On P-21 variety, application ameliorant (cow manure, gypsum, sunhemp, and rice straw) significant decreasing content of sodium, but on Bisma variety, application cow manure and gypsum more effective decrease content of sodium than without ameliorant, sunhemp and rice straw. Mechanism ameliorant reducing salinity stress in P-21 and Bisma were reducing the uptake of ion Cl^- in shoot of maize and storage ion Cl^- in root (Figure 3), which it showed with an application of ameliorant reducing Cl shoot/root ratio.

The land was used for research has pH 8,6. Exchange of Sodium (Na-dd) can occur in saline soil have a characteristic pH 8.5 (Zhang, 2014). Soil pH affects the levels of ion Na^+, whereas high ion Na^+ can inhibit the absorption of potassium from the soil (Hansen *et al*., 2004; Patel *et al.,* 2013). Excess levels of Na^+ in plant tissues reduce the content of ions K^+, whereas potassium has the function to maintaining the osmotic potential, absorption the water and reducing photosynthetic capacity due to chlorophyll degradation caused a high concentration of Cl^-(Tavaccoli *et al.,* 2010). Application cow manure and gypsum on P-21 and Bisma increasing potassium content (Figure 4A). Increasing potassium content also increasing the content of phosphorus (Figure 4B) and nitrogen (Figure 5). Application of cow manure and gypsum reducing salinity stress on maize varieties (P-21 and Bisma) through increasing nutrient content (Singh and Singh, 2014; Mahabub *et al*., 2016).

There were significant correlations between leaf area, nitrogen content, shoot dry weight and grain weight (Table 1). Nitrogen content significant increase shoot dry weight, with the correlation coefficient was r = 0.592. Correlation with leaf area and grain weight was positive (r = 0.832), increasing leaf area was increasing grain weight. The same trend correlation for shoot dry weight with grain weight, wherein increasing shoot dry weight was increased grain weight (r = 0.795) (Figure 6). There were negative correlation between sodium content and shoot dry weight and sodium content and grain weight (Figure 7). Increasing sodium content was decreasing shoot dry weight (r = 0.739) and grain weight (r = 0.862).

Table 1. Significance of analysis correlations response varieties of maize to application of ameliorants on shoot dry weight, leaf area, Nitrogen content, Sodium content and grain weight in saline soil Lamongan, Indonesia

	Leaf area	Shoot dry weight	Nitrogen Content	Sodium (Na) Content
Shoot dry weight	0.951**	1	0.766*	-0.874**
Grain weight	0.885**	0.845**	0.590	-0.911**

**= correlation is significant at α = 0.01, *= correlation is significant at α 0.05

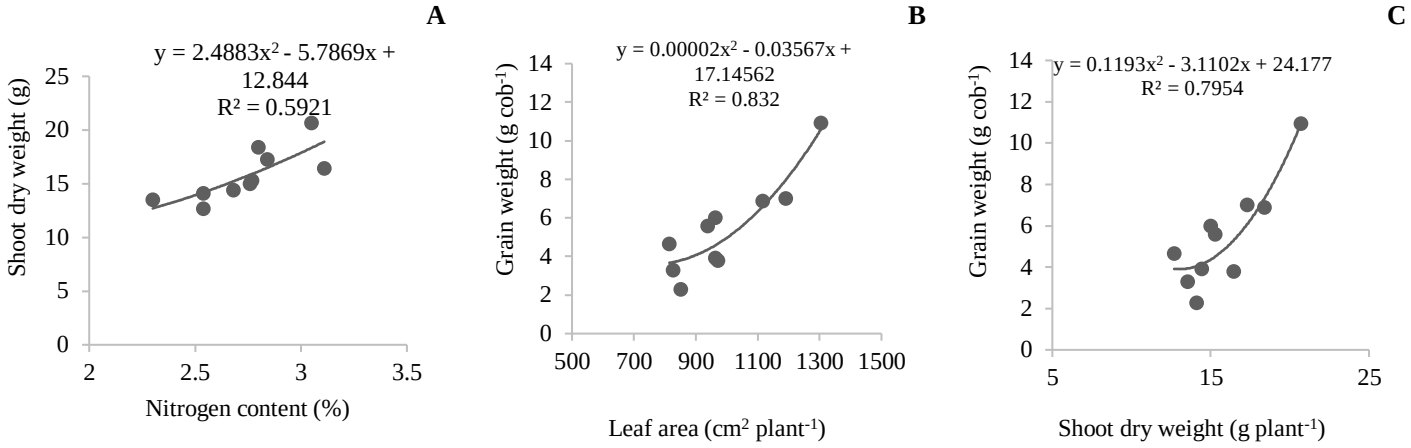

Figure 6. Regression of Nitrogen content with shoot dry weight (A), Sodium content with shoot dry weight (B) and shoot dry weight with grain weight (C).

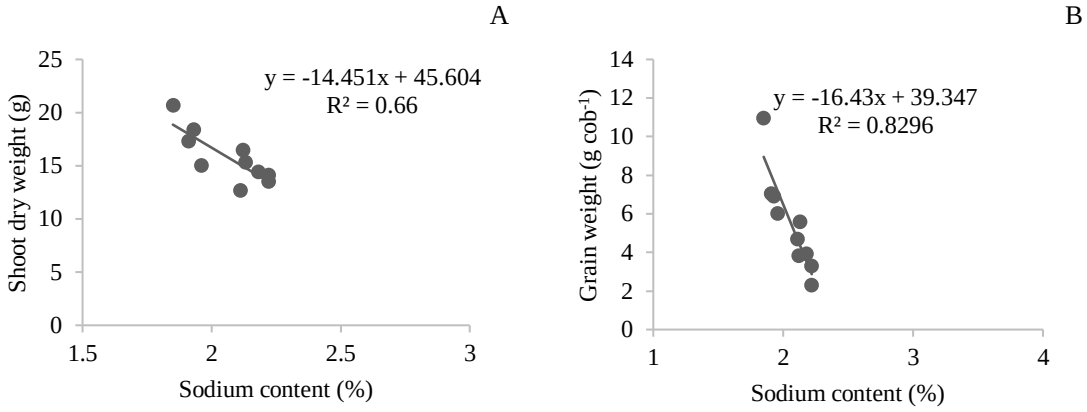

Figure 7. Regression of Sodium content with shoot dry weight (A) Sodium with grain weight (B).

Increasing sodium content in the plant would reduce 31.15 g shoot dry weight and 22.91 g grain weight. Reduction of yield due to a high concentration of sodium was also reported by Eker *et al.* (2006) and Usman *et al.* (2012) on maize and Abbas *et al.* (2013) on wheat.

CONCLUSION

Application of ameliorant decreases salinity stress in two varieties of maize with decrease content of proline, sodium, chlor, and increasing uptake nitrogen, potassium, and phosphorus. On P-21 variety, application of gypsum effective to increase plant growth and grain weight, whereas on Bisma variety cow manure and gypsum increasing plant growth and grain weight. Further, application ameliorant gypsum or cow manure can be used in cultivation maize in saline soil.

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Conflict of interest. The authors declare no conflict of interest.

Data availability. Data are available with the corresponding author (wiwin.fp@ub.ac.id) upon reasonable request

Compliance with ethical standards. This research does not work involved human subject, therefore there was no need for approval by the Research Bioethics Committee of the Faculty of Agriculture, Universitas Brawijaya, Indonesia.

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