INTRODUCTION

Expansion sugarcane cropping area in Indonesia is directed to marginal land because the available arable land is mainly used for food crops. One of the marginal land which is used for sugarcane plantation is saline soil which is spread out along the north coastal region of Java Island (Sembiring, Gani, & Iskandar, 2008). High concentration of salt in soil solution has a negative effect on growth and development of sugarcane. To minimize the negative effect of high salt concentration on sugarcane growth, management of saline soil becomes the essential factor in the success of the expansion sugarcane cultivation area in the saline soil. As part of production management, the effort is subjected by using soil amendment combined with plant nutrition, especially nitrogen.

Sugarcane has been classified as moderate to moderately sensitive to salinity (Hussain et al., 1997; Nelson & Ham, 2000). The deleterious effects of salt concentration on growth and yield of sugarcane have been reported by many researchers (Cavalcante Granja et al., 2018; Lingle & Wiegand, 1997; Rai & Singh, 2013). Hussain, Khan, Ashraf, Rashid, & Akhtar (2004) noted that growing media with medium salt concentration reduced growth of two sugarcane tested cultivars. Previously, Joshi & Naik (1980) reported that excess of salt had negative effect on sugarcane which was indicated by inhibition of growth, reduced chlorophyll synthesis, and decreased uptake of K+ and Ca++. Furthermore, Anitha, Mary, Savery, Sritharan, & Purushothaman (2015) found that elevation of salt concentration of the shoot reduced in root length, leaf area, total chlorophyll, and cell membrane stability of both varieties CoC 671 and CoC 24 of sugarcane.

High salt content in soil elevates high osmotic potential of the soil solution that inhibits water and nutrient uptake (Maie Mohsen, Abo-Kora, & Abeer Kassem, 2016). Many researchers reported the role of vermicompost in alleviating negative characteristics of degraded saline soil.
Saline soil influences available soil nitrogen for supporting growth of plant due to depression of N mineralization (Pathak & Rao, 1998). The mineralization of nitrogen in saline is low because the microbial community and activity are inhibited (Hassan, Abd, & Ahmed, 2016; Singh, 2016). Addition of vermicompost to such degraded soil has been proved to increase nitrogen mineralization (Flores-Sanchez, Pastor, Rossing, Kropff, & Lantinga, 2016; Walpola & Wanniarachchi, 2009).

Nitrogen is an essential nutrition required by sugarcane for supporting its growth and yield (Wiedenfeld & Enciso, 2008). Addition of nitrogen and vermicompost may have synergistic effects on sugar cane grown in saline soil. The objective of the research was to measure the effects of vermicompost and nitrogen on N, P, K, Na uptake, and growth of sugarcane in saline soil.

MATERIALS AND METHODS

The experiment was conducted at Malang Research Station of Indonesia Research Institute for Sweetener and Fiber Crops with altitude of 534 m above sea level and average temperature of 27-29°C from May up to December 2018. Commercial sugarcane variety of 'Bululawang (BL)' was planted in the saline soil with EC of 4.12 dS/m.

The saline soil for planting media was chosen from sugarcane expansion cultivation area of Lamongan District, East Java with coordinate of 06°54'41.10"S and 112°11'46"E. Soil was collected randomly from 10 points by digging them at the depth of 20 cm, and then the soil was air dried in the soil preparation room. Dried soil was sieved in 2 mm filter to remove gravels. Finally, 20 kg of the sieved soil was placed in the plastic pot (30 cm in diameter and 38 cm in depth). About 200 g of the dried sieved soil was taken to be analyzed in order to determine the characteristics of the saline soil.

The treatments consisted of two factors, i.e.: (1) Vermicompost and (2) Nitrogen fertilizer. Three rates of vermicompost tested were (1) 0 t/ha, (2) 10 t/ha (equivalent to 100 g/pot), and (3) 20 t/ha (equivalent to 100 g/pot). The rates of nitrogen fertilizer with source of Amonium Sulpathe (ZA) were (1) 50 % recommended N rate (2.50 g/pot), (2) 75% recommended N (3.75 g/pot), (2) 100% recommended N rate (5 g/pot). Those treatments were arranged using Randomized Block Design with four replicates.

Sugarcane was planted in the pot using one bud set. Vermicompost was mixed thoroughly five days prior to planting. Nitrogen fertilizer (ZA) was added twice, half doses at one month after planting and the rest was applied 2 month after planting. Addition of P fertilizer (SP36) was conducted at one month after planting, while K fertilizer (ZK) was applied at 2 months after planting.

Irrigation was done using tap water with interval 5 days. Volume of water added was based on soil field capacity. Hence, pot plus soil was weighed to calculate the difference between water content of the media and water content of soil field capacity to determine volume of water added. Weeding was done manually when necessary.

Measurement of growth parameters was started at 2 months after planting and to be repeated with interval of one month until 4 months after planting. The observed growth parameters were stem height, stem diameter and number of tillers. Changes of soil media EC was monitored once a month started at 2 months after planting. Soil sample of each treatment was taken at the depth of 10 cm and then it was analyzed for EC. Biomass of sugarcane (stem, leaf and root) was collected at 4 months after planting. Fresh weight of biomass was measured by digital scales. After that, fresh biomass was dried using oven at 120°C for 4 days. Dried biomass was then weighted using digital scales. N uptake by plant was analyzed using Kjeldahl method, P uptake was analyzed using Olsen method, while K uptake was measured by flame photometer.

The collected data were analyzed using ANOVA to determine the effect of the treatments being applied. The mean comparisons were conducted using Least Significant Differences at p = 0.05.

RESULTS AND DISCUSSION

The soil used as a sugar cane growing media has very low in soil organic content, low content of total nitrogen and available P (Table 1). In contrast, the soil contains very high EC (4.12 dS/m) and exchangeable sodium (1.68%). The high EC value of the soil might be due to irrigation or intrusion of...
sea water. The site of collected soil sample is part of northern Java Sea and the distance is about 0.5 km from the sea.

Very high content of EC and exchangeable Na of the soil might not suitable for sugarcane because high salt content in soil cause inhibition of growth, chlorophyll synthesis, PEPC ase activity, and decreased the uptake of K⁺ and Ca⁺⁺ ions of sugarcane (Joshi & Naik, 1980). In addition, Cruz, da Costa Ferreira Júnior, & dos Santos (2018) found that Na accumulation declined plant growth and elevated electrolyte leakage with destruction to the photochemical part of photosynthesis.

Addition of vermicompost, nitrogen fertilizer, and the interaction between vermicompost and nitrogen had significant effect (p < 0.05) on soil EC, N and K uptakes, and Na/K ratio. In general, application of vermicompost together with nitrogen fertilizer was able to eliminate the negative effect of saline soil, hence they induced the growth of sugarcane after 4 months planting.

The interaction between vermicompost and nitrogen rate had significant effect on EC. Addition of vermicompost together with nitrogen significantly decreased EC value of the soil (Fig. 1). Elevating N rates at the same amount of vermicompost did not effect on EC value at every month of measurement. However, increasing addition of vermicompost rates at the same rate of nitrogen decreased EC content of the soil at each month of observation. At 2 and 3 months observation, the lowest EC value was found at the soil with addition of 20 t vermicompost and 75 kg N/ha, i.e. 3.39 dS/m and 3.11 dS/m, respectively. After 4 months planting, the lowest value of EC (3.04 dS/m) was detected at additional 20 t vermicompost and 50 kg N/ha.

Table 1. The characteristics of the saline soil used for sugarcane growing media

| Soil characteristics                   | Content/value | Category |
|----------------------------------------|---------------|----------|
| EC (dS/m)                              | 4.12          | Very high|
| pH                                     | 7.10          | Neutral  |
| Organic-C (%)                          | 0.98          | Very low |
| Total N (%)                            | 0.13          | Low      |
| Available P (ppm)                      | 8.61          | Low      |
| Exchangeable K (me/100 g)              | 0.40          | Medium   |
| Exchangeable Na (me/100 g)             | 1.68          | Very high|
| Cation Exchange Capacity (me/100 g)    | 37.8          | High     |
| Sand (%)                               | 9             |          |
| Silt (%)                               | 20            | Clay     |
| Clay (%)                               | 71            |          |

Fig. 1. Effect of interaction between vermicompost and nitrogen rate on soil EC at 2, 3, 4 months after planting of sugarcane (V= Vermiopost, V0 = 0 t/ha, V10 = 10 t/ha, V20 = 20 t/ha, N50 = 50 kg N/ha, N75 = 75 kg N/ha, N100 = 100 kg N/ha)
**N, K Uptakes and Na/K Ratio**

Interaction of vermicompost and nitrogen fertilizer had significant effect on N, K uptakes, and Na/K ratio. Addition of vermicompost and nitrogen in saline soil significantly affected N uptake by sugarcane after 4 months planting. In the absence of vermicompost (V0), the increase of N fertilizer rate significantly declined the amount of N taken up by sugarcane. However, when the amount of vermicompost increased, the amount of N absorbed by sugarcane were accordingly escalated (Fig. 2). Similar finding was also reported by Yourtchi, Hadi, & Drazi (2013) that confirmed the nitrogen of potato tuber treated with vermicompost and nitrogen in the soil was higher than that with no vermicompost application.

After 4 months planting, the highest N uptake (2.77 g/plant) was observed in sugarcane planted for 4 month in saline soil which was added with 20 t vermicompost plus 50 kg N/ha (V20N75), while the lowest N uptake (1.54 g/plant) was found at sugarcane with no addition of vermicompost 75 kg N/ha (V0N75).

K uptake of sugarcane planted in saline soil was significantly affected by interaction of vermicompost and N fertilizer (Fig. 3). The highest value of K (0.31 g/plant) taken up at 4 months was found at sugarcane treated with 20 t vermicompost and 40 kg N/ha (V20N50). In contrast, addition of N fertilizer at the rate of 75 kg N/ha with no vermicompost (V0N75) caused the least K uptake (0.16 g/plant). Similar results were also reported by Kandan & Subbulakshmi (2015) and Mahmud, Shamsuddoha, Issak, Haque, & Achakzai (2016). These conditions were usually attributed to chemical content of vermicompost which are rich in nutrients.

Na/K ratio in sugarcane planted in saline soil was significantly influenced by interaction of vermicompost and N fertilizer rate. The different effects of the treatments being applied on Na/K ratio were presented in Fig. 4. The highest Na/K ratio (18.4) was observed on the plants treated with 75 kg N/ha and absent of vermicompost (V0N75). The application of vermicompost was appeared to minimize Na/K ratio. Hence, the lowest value of Na/K ratio (9.7) was noted at the treatment of saline soil with addition of 20 ton vermicompost and 50 kg N/ha (V20N50). Kopittke (2012) reported that addition of K+ was observed to alleviate the toxic effects of Na+ on root elongation of cowpea (Vigna unguiculata L.). In present study, Na/K ratio in sugarcane biomass decreased due to addition of vermicompost and N fertilizer might have positive effect on inducing the growth of sugarcane.

![Fig. 2. Effect of interaction between vermicompost and nitrogen rate on N uptake of sugarcane (V= Vermicompost, V0 = 0 t/ha, V10 = 10 t/ha, V20 = 20 t/ha, N50 = 50 kg N/ha, N75 = 75 kg N/ha, N100 = 100 kg N/ha)](image-url)
Fig. 3. Effect of interaction between vermicompost and nitrogen rate on K uptake of sugarcane (V= Vermicompost, V0 = 0 t/ha, V10 = 10 t/ha, V20 = 20 t/ha, N50 = 50 kg N/ha, N75 = 75 kg N/ha, N100 = 100 kg N/ha)

Fig. 4. Effect of interaction between vermicompost and nitrogen rate on Na/K ratio of sugarcane (V= Vermicompost, V0 = 0 t/ha, V10 = 10 t/ha, V20 = 20 t/ha, N50 = 50 kg N/ha, N75 = 75 kg N/ha, N100 = 100 kg N/ha)
Sugarcane Growth

Addition of vermicompost, nitrogen, and their interactions had significant influence (p < 0.05) on plant growth of sugarcane which were reflected from stalk length, number of tillers, and stem diameter of sugarcane after 2, 3 and 4 months planting. At 2 months, the application of both vermicompost and nitrogen increased stalk length (Fig. 5). The longest stalk of sugarcane (10.71 cm) was observed on the plants treated with 20 t vermicompost and 75 kg N/ha. After 3 and 4 months, sugarcane which had the longest stalk was detected on the plants supplemented with 20 t vermicompost and 50 kg N/ha with the value of 16.72 and 17.12 cm, respectively.

At the present study, number of tillers of sugarcane was significantly affected by interaction of vermicompost and nitrogen rate. Number of tillers was increased significantly in accordance with the increase of the amount of vermicompost and nitrogen fertilizer, especially after 3 months planting (Fig 6). At 4 months, the highest number of tillers (11.27) was obtained from the plants treated with 10 t vermicompost and 75 kg N/ha, while the lowest number of tillers (1.01) was noted at those with only 45 kg N/ha with no vermicompost.

Interaction of vermicompost and N fertilizer had a significant effects on stem diameter of sugarcane which was planted in saline soil after 2, 3, and 4 months. Increasing the amount of vermicompost and N fertilizer resulted in the increase of stem diameter. Plants with biggest stem diameter were found in saline soil treated with 20 t vermicompost and 75 kg N/ha (V20N75) with values of 8.56 mm (2 months), 11.88 mm (3 months) and 18.06 mm (4 months) (Fig. 7). In contrast, the smallest stem diameter of sugarcane at 2, 3 and 4 months were observed in saline soil added with 50 kg N/ha only.

Biomass of sugarcane accumulated during 4 months grown in saline soil was significantly affected by interaction of vermicompost and N fertilizer rate. Increasing amount of vermicompost and N fertilizer induced sugarcane to accumulate more fresh and dried biomass (Fig. 8). Treatment of 20 t vermicompost and 50 kg N/ha (V20N50) yielded the weighest fresh (77.67 g) and dried biomass (29.2 g) of sugarcane after 4 months. Treatment of additional 10 t vermicompost and 100 kg N/ha (V10N100) was not significantly different to the treatment that produced the weighest biomass (V20N50).

![Fig. 5. Effect of interaction between vermicompost and nitrogen rate on stalk length of sugarcane at 2, 3, 4 months after planting (V= Vermicompost, V0 = 0 t/ha, V10 = 10 t/ha, V20 = 20 t/ha, N50 = 50 kg N/ha, N75 = 75 kg N/ha, N100 = 100 kg N/ha)](image-url)
Fig. 6. Effect of interaction between vermicompost and nitrogen rate on number of tiller of sugarcane at 2, 3, 4 months after planting (V= Vermicompost, V0 = 0 t/ha, V10 = 10 t/ha, V20 = 20 t/ha, N50 = 50 kg N/ha, N75 = 75 kg N/ha, N100 = 100 kg N/ha)

Fig. 7. Effect of interaction between vermicompost and nitrogen rate on stem diameter of sugarcane at 2, 3, 4 months after planting (V= Vermicompost, V0 = 0 t/ha, V10 = 10 t/ha, V20 = 20 t/ha, N50 = 50 kg N/ha, N75 = 75 kg N/ha, N100 = 100 kg N/ha)
CONCLUSION

Addition of vermicompost together with N increased N and K uptakes, and growth of sugarcane in saline soil. Application of 20 t vermicompost and 50 kg N/ha induced highest N and K uptakes by plants and biomass of sugarcane after 4 months planting.

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