Universal Journal of Agricultural Research 10(6): 660-666, 2022 http://www.hrpub.org
DOI: 10.13189/ujar.2022.100607

Application of Earthworm Manure (EWM) and NPK Fertilizer to Improve the Quality of Acid Sulphate Soil (ASS) as a Sweet Corn (*Zea mays* L) Cultivation Land in North Sumatra, Indonesia

Basyaruddin[1,*], Khusrizal[2]

[1]Faculty of Agriculture, Islamic University of North Sumatra, Medan 20217, North Sumatra, Indonesia
[2]Faculty of Agriculture, Universitas Malikussaleh, Reuleut, Muara Batu, 24355 Aceh Utara, Aceh, Indonesia

Received July 31, 2022; Revised September 30, 2022; Accepted October 25, 2022

Cite This Paper in the Following Citation Styles

(a): *[1] Basyaruddin, Khusrizal , "Application of Earthworm Manure (EWM) and NPK Fertilizer to Improve the Quality of Acid Sulphate Soil (ASS) as a Sweet Corn (Zea mays L) Cultivation Land in North Sumatra, Indonesia," Universal Journal of Agricultural Research, Vol. 10, No. 6, pp. 660 - 666, 2022. DOI: 10.13189/ujar.2022.100607.*

(b): *Basyaruddin, Khusrizal (2022). Application of Earthworm Manure (EWM) and NPK Fertilizer to Improve the Quality of Acid Sulphate Soil (ASS) as a Sweet Corn (Zea mays L) Cultivation Land in North Sumatra, Indonesia. Universal Journal of Agricultural Research, 10(6), 660 - 666. DOI: 10.13189/ujar.2022.100607.*

Abstract A field trial has been carried out in order to study the use of Earthworm Manure (EWM) and NPK fertilizer to improve the quality of Acid Sulphate Soil (ASS) as a sweet corn (*Zea mays* L) cultivation land in North Sumatra. The experiment was a Factorial Randomized Block Design. Factors studied were Earthworm Manure (EWM) and NPK fertilizer. The EWM treatment was arranged in 4 doses consisting of: Control (0 kg EWM / plot), 0.4 kg EWM / plot; 0.8 kg EWM / plot; and 1.2 kg EWM/plot. NPK treatment was given in 4 doses consisting of: control (0 kg NPK / plot); 5 g NPK / plot; 10 g NPK / plot; and 15 g NPK / plot. The treatment of EWM material was applied by mixing EWM with topsoil of ASS at a depth of about 5 cm evenly in each trial plot when it was 1 week before sweet corn plant was planted. While NPK fertilizer treatment was given between the rows of plants when the plants are 2 weeks old. Each treatment was given in each trial plot with a size of 100 cm x 100 cm and was repeated 3 times. The plant spacing was set at 60 cm x 70 cm, the distance between replications was 50 cm, and the distance between treatment plots was 30 cm. Variables observed include some soil properties, growth and crop yields. Soil properties were measured consisting of: pH (H_2O), total N (Kjeldahl), P (Bray II), Exchangeable-K (K-ex) (NH_4OAc pH 7.0). Growth and yield of plants were also determined including: plant height, stem diameter, and crop yield. The results obtained showed that the application of EWM could improve the quality of ASS properties shown by the increase in the total N content, available P, exchangeable-K, and ASS pH and plant growth based on stem diameter growth. NPK application increases total N content, available P, and K-ex, but does not increase growth in height, stem diameter, number of leaves, and crop yields. Application of EWM increases pH, whereas NPK has no effect on ASS pH. The effects of EWM and NPK interact positively on total N content where the application of EWM increases the effect of NPK on total N content; the effect of EWM was better in improving the chemical properties (N, P, K, and pH) of ASS and plant stem diameter growth compared with NPK application. EWM can be used to improve the quality of chemical properties (N, P, K, and pH) and partially or completely substitute NPK sweet corn plants in ASS so as to save on the use of NPK fertilizer. Therefore, EWM has the potential as an alternative agrobiotechnology product that has the opportunity to be used to overcome the problem of ASS as agricultural land.

Keywords Acid Sulphate Soil (ASS), Earthworm Manure (EWM), NPK Fertilizer, pH, Sweet Corn, N

Content, Available-P, Exchangeable-K

1. Introduction

Acid Sulphate Soil is a type of soil that is formed in swampy areas. This soil is affected by the state of water and contains sulfidic material (sulfur clay) which contains a lot of pyrite (FeS_2) [4,26]. If the soil is reclaimed, the pyrite compound (FeS_2) will be exposed to the air and can be oxidized to form ferric hydroxide ($Fe(OH)_3$), sulfate (SO_4^{2-}) and hydrogen ions (H^+) so that the soil becomes very acidic with a low pH [3,5]. In addition its low pH, the ASS fertility status has also been classified to be low which is characterized by N, P-available, K-ex., P fixation is high by Al and Fe [30]. The specific characteristic of this ASS becomes a serious obstacle in the development of the soil for crop cultivation, that this land was classified as problematic soil [9,24,20].

To increase the yield of sweet corn, a production facility in the form of good fertilization technology is needed. In the current condition, the availability of fertilizer tends to be increasingly scarce and subsidies from the government are increasingly reduced so that the price of fertilizer is more expensive and more difficult to obtain. Efforts to improve and maintain production stability need to be sought and applied appropriate, inexpensive and easily available technology as an alternative to replace the role of inorganic fertilizers [2,8].

One way to overcome the problems at ASS is by adding organic material. Provision of organic material in addition to being a nutrient supplier can also improve the quality of the chemical and biological properties of the soil [6,17]. Organic matter can act as a source of organic acids that can play a role in controlling the solubility of metals in the soil [6]. Organic acids are able to degrade toxic substances in the soil so that they are not harmful to plants, and also reduce the amount of phosphate fixed by Fe and Al through a chelation mechanism so that it can increase the P-available to plants [10,27]. Thus organic fertilizer has advantages, especially of an environmentally friendly material [21,7].

Earthworm Manure (EWM) is a by-product of earthworm cultivation in the form of organic material which has undergone decomposition by earthworm activity. According to van Groenigen et al. [28] and Medina-Sauza et al.[7] this material is expected to be able to improve the natural quality of ASS because EWM contains nutrients needed by plants such as N, P, K, Ca, Mg, S. Fe, Mn, AI. Na, Cu. Zn, Bo and Mo. It also contains organic material that can be a source of nutrients for soil microbes that function to decompose organic matter thus releasing nutrients and improving soil physical properties, EWM high pH can help to neutralize the ASS low pH, and EWM has the ability to retain water by 40-60%. These characteristics can support to create soil ecosystem that eases absorption of nutrients by plants root [1,7].

Estimation is based on empirical data collected that EWM can play a role in improving the quality of ASS through improving its the ability to retain water, provide nutrients for plants, improve soil structure and neutralize soil pH. This role is believed to occur because the EWM structure has spaces that are able to absorb and store water which helps it to maintain soil moisture [1,14,15]. With this role, EWM has the potential as an alternative agrobiotechnology product to improve the quality of ASS and add nutrients, especially to substitute and utilize NPK efficiently. However, research into the use of EWM as an effort to find alternative technologies to improve ASS is still relatively limited. Therefore, the research objective is designed to examine the effectiveness of EWM and NPK fertilizer and their interactions in improving the quality of ASS properties as land for sweet corn (*Zea mays* L) cultivation.

2. Materials and Methods

A field trial was conducted at the ASS which lay in the East of Sumatra Island. The location of the study was in Secanggang Village, Langkat Regency, North Sumatra. The position of the field location was close to the beach, flat topography, and exposition leading to East. The experimental area has a length of 21.4 m and a width of 7 so that the area is 149.8 m^2. Rainfall 1842 mm/year with 136 rainy days/year [31].

The materials used consist of sweet corn seeds, EWM organic material and NPK 15:15:15 fertilizer. EWM organic material is collected from cultivation of earthworm as a by product. Organic materials used as a medium for cultivating earthworms are rice straw and municipal waste. Several chemical properties of EWM and ASS were analyzed. Properties of EWM analyzed included moisture content ([wet weight-dry weight]/wet weight x 100%), pH-H_2O (pH-meter), organic C (Walkley and Black), total N (Kjeldahl), P (Bray-II) by using Spectrophotomter, and exchangeable-K (K-ex) (NH_4OAc pH 7.0) and are measured by using a Flamephotometer. While the analysis of ASS properties was also carried out on the same properties as EWM, except for water content and organic matter.

This research uses Factorial Randomized Block Design. Factors studied were Earthworm Manure (EWM) and NPK fertilizer. The EWM treatment was arranged in 4 doses consisting of: Control (0 kg EWM/plot), 0.4 kg EWM/plot; 0.8 kg EWM/plot; and 1.2 kg EWM/plot. The 4 dose NPK treatment consisted of: control (0 kg NPK / plot); 5 g NPK / plot; 10 g NPK / plot; and 15 g NPK / plot. Each treatment was repeated 3 times and given in each trial plot measuring 100 cm x 100 cm.

The treatment of EWM material was done by spreading and mixing EWM material to a depth of about 5 cm ASS in each trial plot when the plant was 1 week old before the sweet corn seeds were planted. While NPK fertilizer treatment was applied by spreading NPK according to the rows of plants when the plant was 2 weeks old. Variations in the time of EWM application 1 week after planting in the hope of providing an opportunity for mineralization of nutrients in EWM to release available nutrients, while NPK is given at 2 weeks of age to prevent N loss and NPK dissolves more quickly to release nutrients to the soil. Each treatment was given in each trial plot with a size of 100 cm x 100 cm and was replicated 3 times. Planting was arranged with a spacing of 60 cm x 70 cm. To prevent mutual influence between the plots, trenches 50 cm wide were made with a depth of about 10 cm between replicates and about 30 cm wide and 10 cm between treatments.

Variables observed include some soil properties, growth, and crop yields. Soil samples were collected at a depth of about 15 cm in each treatment plot and the same replicates. All soil samples from the same replicate were composited. Soil properties determined consisted of: pH-H_2O measured by using pH-meter, total N (Kjeldahl), P (Bray-II) measured by using Spectrophotomter, and exchangeable-K (K-ex) (NH_4OAc pH 7.0) measured by using a Flamephotometer. Plant growth and yields that were also determined include: plant height was measured with a meter from the first segment to the highest shoot of the plant, stem diameter was measured at 2-3 stem segments with a schlifier-meter, fresh yield per plant (weight of corn cobs per plot and per plant) was measured with a digital scale.

3. Results and Discussion

3.1. Soil Properties of ASS and EWM

The initial results of the analysis of some of the properties of ASS are shown in Table 1. Table 1 shows that ASS has a very high degree of acidity or low pH (pH 3.0). The macro nutrient content of soil N and P was classified as low, K and Mg belong to medium and high respectively. So both acidity (pH) and nutrients are a ASS problem when used as agricultural cultivation.

Table 1. Initial Results of Analysis of Some Chemical Properties of ASS Secanggang

Soil Characteristics	Results	Criteria
N (%)	1,24	Low
P (ppm)	3,07	Low
K-ex (me%)	1,07	Medium
Mg-ex (me%)	2,67	High
pH	3,00	Very low

Table 2. Some Chemical Properties of EWM Tested

No	EWM Properties	Value
1	Moisture content (%)	47,8-64,3
2	pH H_2O	6.30-7.58
3	C-organic (%)	30,08-49,46
4	N (%)	1.03-1.37
5	C/N	29.2-36.1
5	P (%)	0,40-0,51
6	K (me%)	1.17-1.48

The results of the analysis of some properties of EWM material are presented in Table 2.

Table 2 shows that the pH of EWM ranges from 6.30-7.58 including high, C-organic content of 30.08-49.46% was very high, P content of 0.4-0.51 % (equivalent to 4000-5100 ppm P) was very high, and K levels range from 1.17-1.48 me%. Based on their properties, EWM has the potential to improve the quality of ASS.

3.2. The Effect of EWM on Several Chemical Properties of ASS

3.2.1. Effect of EWM on Soil pH, N, P, and K-ex

The results of the analysis of the average difference test on the effect of EWM on pH, N, available P, and K-ex of ASS are shown in Table 3.

Table 3. Effect of EWM on pH, N, P, and K-ex in ASS

EWM (kg/plot)	pH_{H2O}	N (%)	P (ppm)	K-ex (me/100g)
Control	4.48a	0.13a	15.19a	0.12a
0.4	4.64b	0.14a	15.31b	0.13b
0.8	4.68b	0.16a	15.46bc	0.14bc
1.2	4.77bc	0.18b	15.66c	0.16c

The number followed by the same letter in one column is not significantly different based on the DMRT test at P: 5%

Table 3 showed that the EWM significantly increased pH, N, available P, and K-ex in ASS. Application of EWM on ASS was positively correlated with pH (r: 0.97*) N (r: 0.99**), P (0.99**), and K-ex (r: 0.98*), which were presented in Figures 1, 2, 3, and 4, respectively.

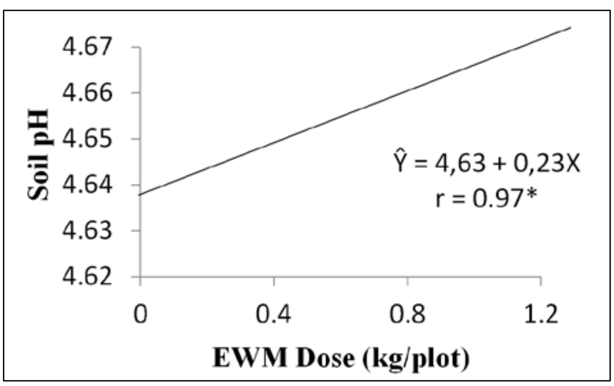


Figure 1. Relationship between EWM dose and Soil pH in ASS

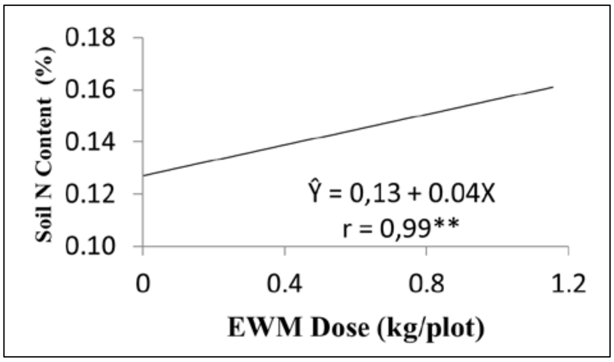


Figure 2. Relationship between EWM Dose and N content (%) in ASS

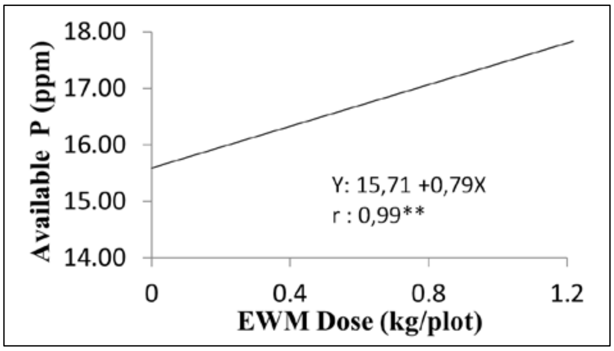
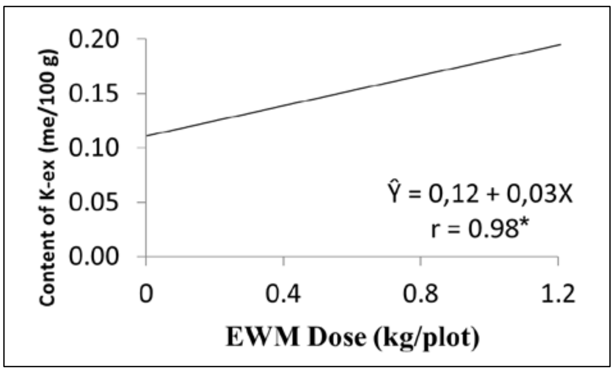


Figure 3. Relationship between EWM Dose and Available P in ASS



'Figure 4. Relationship between EWM Dose and Content of K-ex in ASS

The increase in pH, N, P, and K-ex due to EWM can be explained based on the properties of EWM as shown in Table 2. In Table 2, it can be seen that EWM material has a pH ranging between 6.30-7.58 including high organic-C content of 30.08-49.46% very high, P content 0.4-0.51% (equivalent to 4000-5100 ppm P) very high, with K-ex levels ranging from 1.17-1.48 me%. These characteristics of EWM contribute to increasing soil pH, N, P, and K-ex thus improving the quality of ASS. This is in line with the results of the study by Rossi et al.[22] and Medina-Sauza et al. [7]

3.2.2. The Effect of NPK on Some Chemical Properties of ASS

The effect of NPK on pH, N, P, and K-ex on ASS was shown in Table 4. It revealed that NPK application only significantly increases the content of N, P, and K-ex, but does not affect the pH of ASS.

Table 4. Effects of NPK on pH, N, P, and K-ex on ASS

NPK (g/plot)	pH_{H2O}	N (%)	P (ppm)	K-ex (me/100 g)
Control	4.62	0.12a	14.61a	0.10a
5	4.64	0.15a	15.17b	0.13b
10	4.65	0.16a	15.69bc	0.15bc
15	4.65	0.18b	16.14c	0.17c

The number followed by the same letter in one column is not significantly different according to the DMRT test at P = 95%

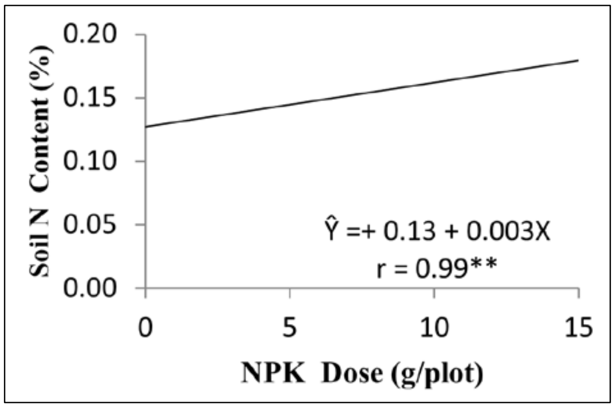


Figure 5. Relationship between NPK Dose and N content (%) in ASS

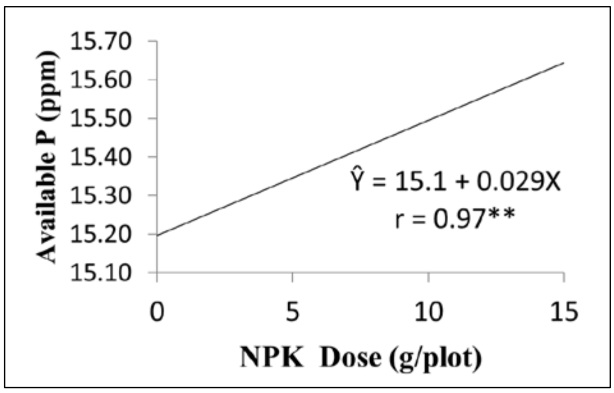


Figure 6. Relationship between NPK Dose and Available P (ppm) in ASS

NPK application was positively correlated with N (r: 0.99**), P (r: 0.97*), and K-ex (0.97*) shown by Figures 5, 6, and 7. The high correlation can be caused by dual terms: the properties of NPK compounds was more easily and quickly dissolves and the condition of the ASS ecosystem was acidic (pH 4.62-4.65). These two aspects support the rate of dissolution of NPK more intensively so that the N, P, and K content in NPK could readily and quickly dissolve [8,13] . This condition increases the content of N, P, and K in the soil. However, NPK fertilizer does not correlate to increase soil pH of ASS.

Very low pH conditions are a major problem in ASS. It has implications for many components of the ASS ecosystem that can inhibit on the plant growth. EWM material has an effect on increasing the pH of ASS (Table 3) while NPK has no effect on pH on ASS (Table 4). It can be explained that EWM has base cation K (1.17-1.48 me%) and pH (6.30-7.58).

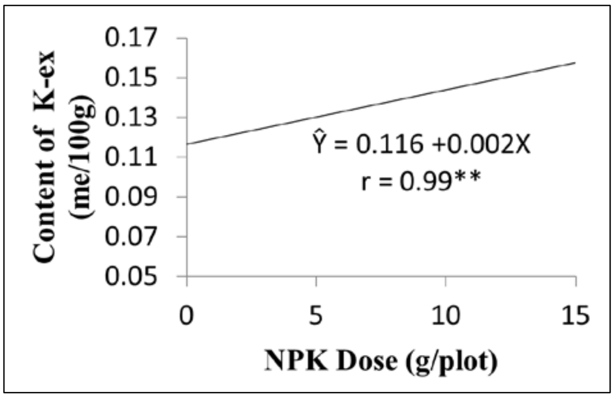


Figure 7. Relationship between NPK Dose and Content of K-ex in ASS

Both of these characteristics of EWM have the potential to play a major role in improving the acidity of higher pH of ASS. According to Garcia-Mentero et al. [9] that earthworms content high of base cation and pH, therefore the soil pH was increased by earthworm applicated. In addition, EWM also has organic matter content ranging from 30.08 to 49.46%. This organic material in addition can play a role in improving the physical properties of ASS [29,12], also has the potential to improve the pH of the soil through the adsorption reaction by organic colloids against H^+ ions in the soil solution so that the pH of the ASS increases. The characteristics of EWM are not owned by NPK fertilizer, so it makes EWM play a better role in improving the pH condition of ASS which was the main problem of ASS when used for agricultural land [23,25] . Therefore, EWM has the potential as an agrobiotechnology product in improving quality and overcoming ASS problems as agricultural land.

3.3. Effect of Interaction between EWM and NPK on N Content in ASS

The effect of the interaction of EWM and NPK applications has been shown in Figure 8 and Table 5. Figure 8 showed that EWM and NPK have positive interactions based on total N content variable. The effect of NPK on the content of total N increases with an increasing dose of EWM. This situation can be caused by EWM having the following characteristics: (1) presence of high organic matter (30.08-49.46%) and moisture content (47.8-64.3%), (2) contains N as much as 1,03-1,37%, and (3) as an energy source that can support microbial activity to carry out mineralization that can release N from organic matter. These characteristics have the potential to increase soil N.. Similarly reported by Kaneko et al. [2], EWM high in NO_3 and P_2O_5. This condition also explains that EWM and NPK have no different roles in increasing soil N. Based on this fact, EWM can be an alternative agrobiotechnology to substitute NPK. In another hand, EWM can replace part or all of NPK fertilizer so that the use of NPK can be saved and efficient.

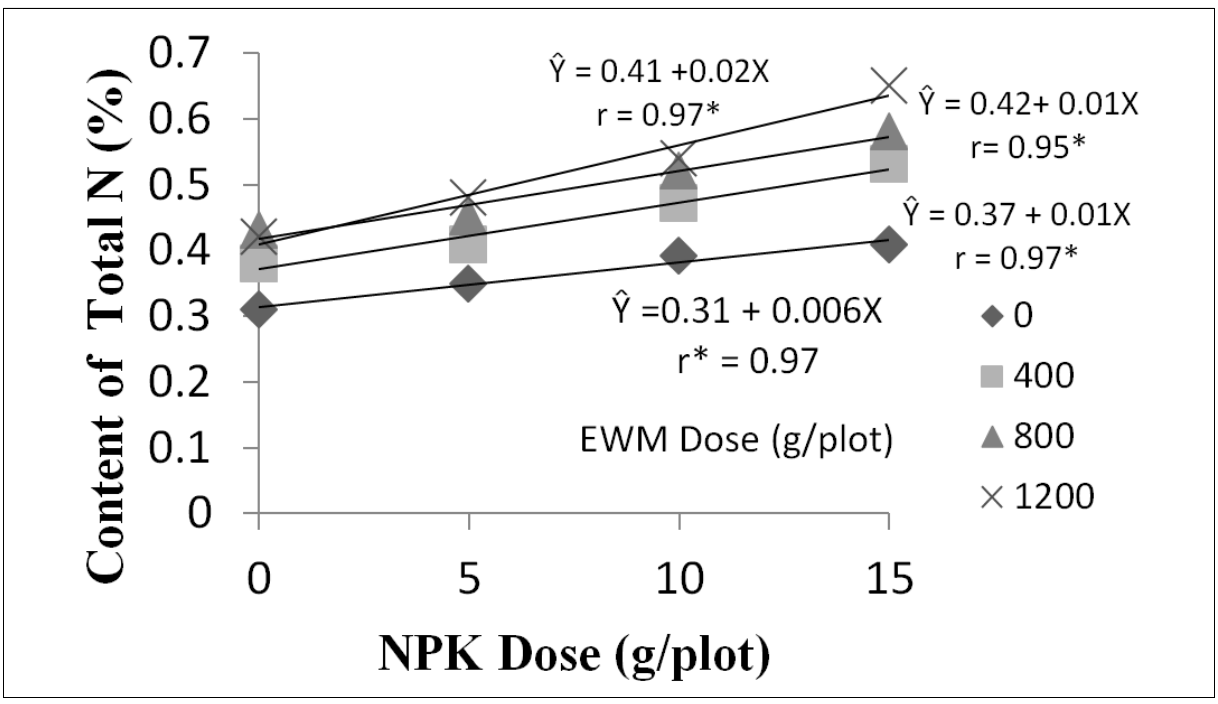


Figure 8. Effect of Interaction between EWM and NPK on total-N Content in ASS

Table 5. Recapitulation of Analysis of the Variance on Single Effects of EWM, NPK and Their Interactions Effects on Growth and Yield of Sweet Corn and Chemical Properties (N, available P, K-ex and pH)

No	Variable Observed	EWM	NPK	Interaction of EWM x NPK
1	Plant height at 2 weeks old	ns	ns	ns
2	Plant height at 4 weeks old	ns	ns	ns
3	Plant height at 6 weeks old	ns	ns	ns
4	Stem diameter at 2 weeks old	*	ns	ns
6	Stem diameter at 6 weeks old	ns	ns	ns
10	Crop yield	ns	ns	ns
11	Content of total N	**	**	**
12	Available P	**	**	ns
13	Contenf of K-ex	**	**	ns
14	pH-H_2O	**	ns	ns

Note: ns=no significant *= significant ** =highly significant

3.4. Effect of EWM, NPK, and their Interactions on Sweet Corn Plants

In addition to some soil chemical properties discussed, the effect of EWM and NPK on the growth and yield of corn plants was also presented in Table 5.

Table 5 shows that, EWM and NPK each had no significant effect on plant height and stem diameter at 6 weeks growth; but had a very significant effect on increasing total N, available P, exchangeable K, and a significant effect on the stem diameter at 2 weeks. Though NPK has no effect on soil pH, the effect of EWM was highly significant. In other words, EWM can play a role in replacing the NPK in part and/or in its entirety. According to Singh [25] earthworm is able to enhance N, P, and K nutrients in the soil.

4. Conclusions and Recommendations

4.1. Conclusion

1. The application of EWM can improve the quality of ASS properties which was shown by increasing the content of N, P, K, and pH of ASS and the growth of stem diameter at 2 weeks of plants.
2. NPK application increases N content, available P, and K-ex soil, but does not increase plant height growth, stem diameter, number of leaves, and crop yield.
3. The application of EWM material increases the soil pH, whereas NPK has no effect on the pH of ASS.
4. The effect of EWM and NPK interact positively where EWM application increases the effect of NPK on the total N content of the soil.
5. EWM has the potential as an agrobiotechnology product that can be used to partially substitute or overall NPK replacement so that it can reduce NPK usage and improve the quality of chemical properties in overcoming problems in ASS as agricultural land.

4.2. Recommendation

As an alternative agrobiotechnology product, the use of EWM still need further research relating to the benefits of EWM residues, obtaining the maximum/optimum dose, the method of production, and engineering of commercially oriented EWM products, and the application method, both for the same type of plant and soil as well as others.

REFERENCES

[1] Ahmed, N. & Al-Mutairi, K.A. (2022). Earthworms effect on microbial population and soil fertility as well as their interaction with agriculture practices. Sustainability, 14, 7803:1-17. https://doi.org./10.3390/su14137803

[2] Beckingham, C. (2007). Sweet Corn Growing. Department Of Primary Industries, New South Wales Government, Australia.

[3] Dent, D. (1986). Acids Sulphate Soils: Baseline for Research and Development. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. 204 p.

[4] DER [Department of Environment Regulation] (2015). Identification and Investigation of Acid Sulfate Soils and Acidics Landscape. Government of Western Australia

[5] Dhanya, K.R., & Gladis, R. (2017). Acid sulfate soils-its characteristics and nutrient dynamics. Asian. J. Soil. Sci. 12(1): 221-227. Doi: 10.15740/HAS/AJSS/12.1/221-227

[6] Ding, Y.Z., Song, Z.G., & Guo, J.K. (2014). Intercation of organic acids and pH on multy-heavy metal extraction from alkaline and acid mine soils. International Journal of Environmental Science and Technology, 11: 33-42

[7] Emadodin, I., Reinsch, T., Rotter, A., Orlando-Bonaca, M., Taube, F., & Javidpour, J. (2020). A perspective on potential of using marine organic fertilizers for the sustainable management of coastal ecosystem services. Environmental Sustainability, 3: 105-115

[8] Fang, P., Abler, D., Lin, G., Sher, A., & Quan, Q. (2021). Substituting organic fertlizer for chemical fertlizer: evidence from apple growers in China. Land. 10, 858: 1-24. https://doi.org/10.3390/land10080858

[9] Garcia-Montero, L.G., Valverde-Asenjo, I., Grande-Ortiz, M.A., Menta, C., & Hernando, I. (2013). Impact of earthworm casts on soil pH and calcium carbonate in black truffle burns. Agroforestry System, 87(4): 815-826. Doi: 10.1007/s10457-013-9598-9

[10] Gmach, M.R., Cherubin, M.R., Kaiser, K., & Cerri, C.E.P. (2020). Processes that influence dissolved organic matter in the soil. Review, Soils and Plant Nutrition Sci. agric. (Piracicaba, Braz.) 77(3). https:/doi.org/10.1590/1678-992X-2018-0164

[11] Hallam, J., Berdeni, D., Grayson, R., Guest, E.J., Holden, J., Lappage, M.G., Prendergast-Miller, M.T., Robinson, D.A., Turner, A., Leake, J.R., & Hodson, M.E. (2020). Effect earthworm on soil physico-hydraulic ang chemical properties, herbage production, and wheat growth on arable land coverted to ley. Science on The Total Environment, 713. https://doi.org/10.1016/j.scitotenv.2019.136491

[12] Kaneko, T., Fujikawa, T., & Mihara, M. (2020). Changes in soil physical and chemical properties with depth due to megascolicidae movements. International Journal of Enviromental and Rural Development. 11(2): 146-153

[13] Khalofah, A., Ghramh, H.A., Al-Qthanin, R.N., L'taief, B. (2022). The impact of NPK fertilizer on growth and nutrient accumulation in juniper (Juniperus procera) trees grown on fire-damage and intact soils. Plos One, 17(1): e0262685. Doi: 10.1371/journal.pone.0262685

[14] Li, Y., Shao, M., Wang, J., & Li, T. (2020). Effect of earthworm cast application on water evaporation and storage in loess soil column experiments. Sustainability, 12, 3112: 1-13. Doi: 10.3390/su12083112

[15] Ma, L., Shao, M., & Li, T. (2020). Characteristics of soil moiture and evaporation under the activities of earthworms in typical anthrosols in China. Sustainability, 12, 6603: 1-11. Doi: 10.3390/su12166603

[16] Michael, P.S., Fitzpatrick, R.W., & Reid, R. (2015). The role of organic matter in ameliorating acid sulfate soils with sulfuric horizons. Geoderma, https://dx.doi.org/10.1016/j.geoderma.2015.04.023.

[17] Medina-Sauza, R.M., Alvarez-Jimenez, M., Delhal, A., Reverchon, F., Blouin, M., Guerrero-Analco, J.A., Cerdan, C.R., Guevara, R., Villain, L., & Barois, I. (2019). Earthworm building up soil microbiota, a review. Front. Environ. Sci. 7: 81. https://doi.org/10.3389/fenvs.2019.00081

[18] Mustapha, A.A., Lawan, B.A., Dawaki, M.U., Magaji, M.J., & Abdulwahab, M. (2017). Solubility of N, P, K, and pH variability as influenced by mineral fertilizer and organic amendment on sandy loam in Kano State. Savannah Journal of Agriculture, 12(2): 30-35

[19] Nurzakiah, S., Indrayati, L., & Nurita (2019). Enhanced soil chemical properties and rice yield in acid sulphate soil by application of rice straw. Journal of Tropical Soils, 17(1): 31-36. Doi: http://dx.doi.org/10.5400/jts.2012.v.171.31-36

[20] Panhwar, Q.A., Naher, U.A., Shamshuddin, J., Othman, R., & Hakeem, K.R. (2016). Management of acid sulfate soils for sustainable rice production in Malaysia. In book: Soil Science : Agriculture and Environmental Perspective. Editors Hakeem et al. Doi: 10.1007/978-3-319-34451-5.4

[21] Rajiv, S., Sunil, H., Dalsukhbhai, V., & Krunalkumar, C. (2009). Earthworms vermicompost: a powerful crop nutrient over the conventional compost soil conditioner against the destructive chemical fertilizers for food safety and security. Am-Euras. J. Agric. & Environ. Sci. 5(S): 01-55

[22] Rossi, J.P., Blanchart, E., & Lavalle, P. (2017). Effect of earthworms on some soil physical and chemical properties: their potential use in the tropical agriculture. Amapeda Annual Meeting, Caribbean Food Crops Security. 428-440.

[23] Salehi, A., Ghorbanzadeh, N., & Kanneh, E. (2013). Eratworm biomass and abundance, soil chemical and physical properties under different poplar plantations in the north of Iran. Journal of Forest Science, 59(6): 223-229.

[24] Shamshuddin, J., Azman, E.A., Shazana, R.S., & Ishak, C.F. (2014). Properties and management of acid sulfate soils in Southeast Asia for sustainable cultivation of rice, oil palm, and cocoa. Advances in Agronomy. 124: 91-142. Doi:10.1016/B978-0-12-800138-7.00003-6

[25] Singh, J. 2018. Role of earthworm in sustainable agriculture. Sustainable Food Systems from Agriculture to Industry. Improving Production and Processing, 2018: 83-122. https://doi.org/10.1016/B978-0-12-811935-8.00003-2

[26] Sukitprapanan, T., Suddhiprakarn, A., Kheoruenromne, I., Anusontpornperm, & Gilkes, R.J. (2015). Forms of acidity in potential, active and post-active acid sulfate sils in Thailand. Thai Journal of Agriculture Science, 48(3): 133-146

[27] Tan, K.H. 2010. Principles of Soil Chemistry. Fourth Edition. Publisher CRC Press. 390 p.

[28] van Groenigen, J.W., Lubbers, I.M., Vos, H.M.J., Brown, G.G., De Deyn, G.B., & va Groenigen, K.J. (2014). Earthworm increase plant production: a meta-analysis. Scientific Reports, 4: 6365: 1-7. Doi:10.1038/srep06365

[29] Xiang, H., Guo, L., Zhang, J., Zhao, B., & Wei, H. (2018). In situ earthworm breeding to improve soil aggregation, chemical properties, and enzyme activity in Papayas. Suistainability, 10, 1193: 1-13. Doi: 10.3390/su10041193.

[30] Zin, K.P., Lim, L.H., Mallikarjunaiah, T.H., & Bandara, J.M.R.S. (2015). Chemical properties and phosphorus fractions in profiles of acid sulfate soils of major rice growing areas in Brunei Darussalam. Geoderma Regional, 6:22-30

[31] BPS Kabupaten Langkat 2018. Curah Hujan dan Banyaknya Hari Hujan Menurut Pengamatan. https://langkatkab.bps.go.id/indicator/151/120/1/curah-hujan-dan-banyaknya-hari-hujan-menurut-daerah-pengamatan-dan-bulan.html