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The Effectiveness of Dolomite Phosphate Rock on Growth and Yield of Black Sesame (*Sesamum indicum* L.) in Paddy Field

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Abstract

Background: The study was carried out to determine the amount of the dolomite phosphate rock (DPR) on the growth and seed yield of black sesame in a paddy field.

Methods: A randomized complete block design was used for the field experiment, which included four treatments, each with four replications. Treatments were applied without the DPR and with 0.25, 0.5 and 1.0 t ha^{-1} DPR.

Result: Experimental results showed that sesame plants were fertilized with the following formula: 60 N × 60 P_2O_5 × 30 K_2O kg ha^{-1}. Moreover, the addition of 0.5 t ha^{-1} DPR increased plant height (129.7 cm), the number of leaves and pods per plant (47.4 pods), total chlorophyll content in leaves (12.4 µg/cm^2), the number of seeds per pod and seed yield (1.61 t ha^{-1}). The phosphate content increased in the stem but not in the leaves and seeds. The pH of the soil (0-20 cm) and the amount of NH_4+, NO_3^- and $P_{Available}$ were also increased.

Key words: Dolomite, Nutrient uptake, Phosphate rock, Sesame.

Introduction

Sesame, scientifically known as *Sesamum indicum* L., belongs to the Pedaliaceae family, is an annual plant and is one of the oldest cultivated plants in the world (Wei *et al*., 2022). The sesame plant is known as the "Queen of Oil Crops" and has high nutritional value (Wang *et al*., 2014). Sesame seeds contain 57%-63% oil, 23%-25% protein (Brewer *et al*., 2016), iron, magnesium, manganese, copper, calcium and essential vitamins, such as vitamins B1 (thiamine) and E (tocopherol) (Najeeb *et al*., 2011). Therefore, sesame is one of the sources of nutrients that improve human health. In the Mekong Delta, Vietnam, sesame is an attractive crop to grow in rotation with rice due to its relatively low nutrient requirements, resilience to low soil moisture (as it is not dependent on post germination irrigation) and heat tolerance (Khuong *et al*., 2022). However, the sesame area in Vietnam is about 34,683 hectares with an output of 28,774.67 tons and our country's sesame yield is still relatively low (0.83 tons/ha) (FAO, 2023) because of poor planting and acidic soil caused by the extensive use of chemical fertilizers (Ning *et al*., 2017; Bhatt *et al*., 2019), which causes the sesame plant roots to grow poorly developed. Phosphorus is one of the essential macronutrients for sustainable plant growth (Yang *et al*., 2012), plays a crucial role in reproductive growth (Kim and Li, 2016; Uygur and Şen, 2018). Due to phospho's low availability and poor recovery from applied fertilizers, phosphorus is the least available macronutrient and hence the most frequently deficient nutrient in most agricultural soils. Phosphorus has a limited availability because, in acidic soil conditions, it easily forms insoluble complexes with cations like aluminum and iron (Hellal *et al*., 2019). In acidic soil, applying phosphorus helps improve pH and reduce aluminum toxicity. Phosphate rock is relatively slow to release soluble P; however, compared to industrial P fertilizers, phosphate fertilizer is low in price, making it a very appealing fertilizer (Hellal *et al*., 2019). Moreover, dolomite is rich in calcium and magnesium and it helps improve soil conditions, such as neutralizing pH and soil structure and helps plants develop good roots (Krismawati *et al*., 2022). According to Chutichude *et al.* (2010), dolomite is frequently utilized as soil fertilizer in a variety of soils for agricultural applications.. Therefore, the study was conducted to determine the effect of the optimal amount of dolomite phosphate rock (DPR) to increase the growth and yield of black sesame.

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Materials and Methods

A local black sesame variety with traits such as short duration growth (approximately 75-81 days), drought tolerance, high yield (1.2-2.0 t ha^{-1}) and oil content (47.5%) was used. The DPR comprised 84% dolomite and 16% phosphate rock (21.43% CaO, 5.0% SiO_2). The experiment was conducted at the My An Hung commune (latitude: 10.390361, longitude: 105.631883), Lap Vo District, Dong Thap Province, Vietnam, from February to June 2022. The characteristics of the initial soil were pH_{H2O} (5.25), pH_{KCl} (4.13), NH_4^+ (24.64 mg kg^{-1}),

NO_3 (20.02 mg kg^{-1}), N_{Total} (0.19%), P_{Total} (0.06%) and $P_{Available}$ (45.83%). The textural class of experimental soil is silty clay.

The field experiment was carried out in a randomized complete block design, which included four treatments, each with four replications (Fig 1). The plot size was 25 m^2. Treatments were applied without the DPR mix (control) and with 0.25, 0.5 and 1.0 t ha^{-1} DPR. The DPR was applied after soil plowing. Mineral fertilizers were applied in this research at the recommended rate of 60 kg N, 60 kg P_2O_5 and 30 kg K_2O per hectare and fertilizing according to farmers. They were divided in two and applied to sesame plants 10 days and 20 days after sowing.

Data collection

Plant height (cm) of 20 plants per plot was measured from the soil surface to the highest growth peak and the number of leaves was counted all leaves of plant 70 days after sowing. The chlorophyll content in a leaf (µg Chl cm^{-1}) was measured 45 days after sowing, according to the N,N-dimethylformamide method (Moran,1982). The number of pods per plant, pod weight, the number of seeds per pod, the weight of 1.000 seeds and yield were determined according to Khuong *et al*. (2022). Nitrate, phosphate and potassium contents in the stem and leaves were measured 50 days after sowing and in seeds, according to Temminghoff and Houba (2004). The 5 sesame plants per replication were collected then dried and mixed for Nitrate, phosphate and potassium analyzation. Furthermore, pH_{H20} (1, soil : 2.5, water), pH_{KCl} (1, soil : 2.5, KCl solution), nitrate, phosphate and potassium values in soil samples (0-20 cm) were measured, as described by Sparks *et al.* (1996). The soil samples were collected from five places in plot then dried and mixed together for pH and nutrion analyzation. Net profitt = revenue " expenses (Jayathilaka, 2020). The cost of raw materials (inorganic fertilizers, DPR, plant protection drugs, seeds, water irrigation), labor and product sales were calculated according to 2022 prices.

Data analysis

The data presented in this research are the mean values of five replications. All data were analyzed using one-way analysis of variance (ANOVA) using SPSS software package version 13.0 and were compared for significant differences in treatment effects using Duncan's test at P<0.05.

RESULTS AND DISCUSSION

Effects of DPR on pH, Nitrate, Phosphate in soil

The results in Table 1 show that the pH levels and the percentage of $P_{Available}$ increased in the soil where DPR was applied compared to those in the soil where DPR was not applied. Similar to the results by Yang *et al.* (2012), in this study, the pH was increased up to three units when the acid sandy soil was applied with DPR. In the work of Suksri (1998), acidic soil was used with dolomite, which also increased the soil pH. According to the study of Lestari *et al.* (2016), the higher the rate of dolomite applied to acid sulfate soil, the greater the pH increase. The increase in soil pH might be due to the high pH of DPR application. The percentage of total nitrate in soil was not significantly different in all the treatments. However, the amount of NH_4^+ and NO_3^- in the soil was higher in all treatments with the application of DPR. According to Silber *et al.* (2010), the soil pH affects both the availability and uptake of nutrients by plants and the release of PO_4^{3-} and NH_4^+ from soil particles (Zheng *et al*., 2013).

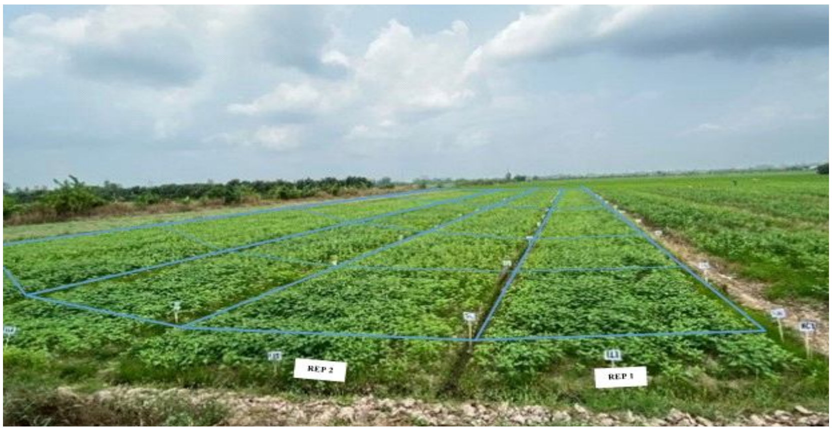

Fig 1: The field experiment.

Table 1: Effects of DPR on pH, NH_4^+, NO_3^-, $P_{Available}$, P_{Total} and N_{Total} in soil.

Treatments	pH_{H2O}	NH_{4+} (mg/kg)	NO_3^- (mg /kg)	$P_{Available}$ (%)	N_{Total} (%)	P_{Total} (%)
Control	5.24±0.21	23.04±2.76	21.96±1.90	46,47±1.16	0.20±0.20	0.070±0.01
0.25 t ha^{-1}	5.75±0.06	26.71±2.75	22.61±2.10	50,16±1.95	0.20±0.20	0.076±0.01
0.5 t ha^{-1}	5.78±0.08	30.55±4.27	31.57±2.86	52,71±3.19	0.22±0.22	0.089±0.026
1.0 t ha^{-1}	5.81±0.12	30.17±2.22	31.65±3.16	52.18±2.45	0.19±0.29	0.076±0.02

Note: Control: Without application of DPR, ± stdev.

Effects of DPR on plant height, number of leaves and chlorophyll content in leaves

Plant height was measured at harvest time and DPR application significantly increased (Fig 2). The greatest plant height (mean value of 129.7 cm) was recorded at the treatment of 0.5 t ha^{-1} DPR and this was significantly higher than the control and 0.25 t ha^{-1} DPR (121.6 and 126.2 cm, respectively). There was no significant difference in plant height when a higher percentage of DPR was applied. The number of leaves on the plant was the highest with a treatment of 1.0 t ha^{-1} DPR and when the application of the DPR was lower, the number of leaves per plant was not significantly different. The results were similar to those obtained by Soeparjono and Kadiyasari (2021) on black soybean, Suntoro *et al.* (2018) and Krismawati *et al.* (2022) on maize. When DPR was applied to ryegrass, the dry weight increased (Yang *et al*., 2012).

The application of DPR was observed to have significant effects on chlorophyll b and total chlorophyll in leaves (Fig 3). However, DPR did not affect the content of chlorophyll a. The total chlorophyll and chlorophyll b were significantly higher than those in the control plants and those treated with 0.25 t ha^{-1} DPR. The chlorophyll content increased in corn plants when they were treated with 0.2 t ha^{-1} dolomite (Suntoro *et al*., 2018). The higher chlorophyll content in leaves treated with DPR might be due to high phosphate uptake in plants (Fig 4). Phosphorus plays a vital role in chlorophyll production and regulation (Billah *et al*., 2020).

Effects of DPR on nitrate, phosphate and potassium in stem, leaves and seeds

Nitrate and potassium contents were not significantly different in stem, leaves and seeds in all treatments (Fig 4). These results were inconsistent with the content ammonium and nitrate in the soil (Table 1). The phosphate content significantly differed in the stem when sesame plants were treated with DPR; however, it was not different in leaves and seeds. Suntoro *et al.* (2018) found that when corn was treated with dolomite, the phosphate concentration in plant was significant higher but dolomite application did not affect to nitrate and potasium contrations. Similar the study of Damrongrak *et al.* (2015) on rubber trees nitrate concentration in leaves was not affected by application of dolomite. According to Rastija *et al.* (2014) the availability

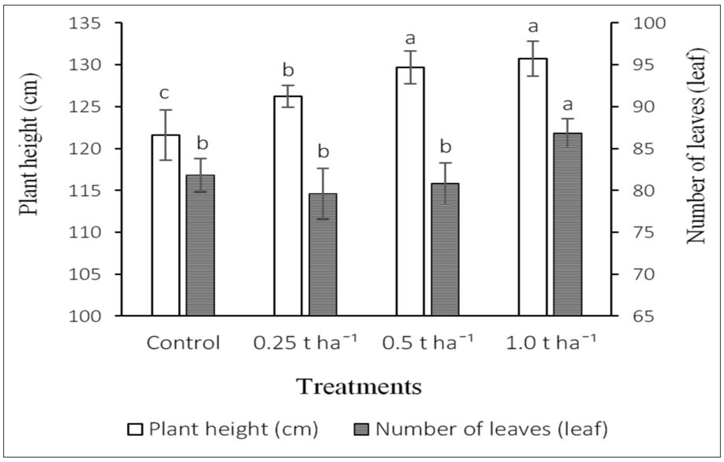

Fig 2: Plant height and the number of leaves.

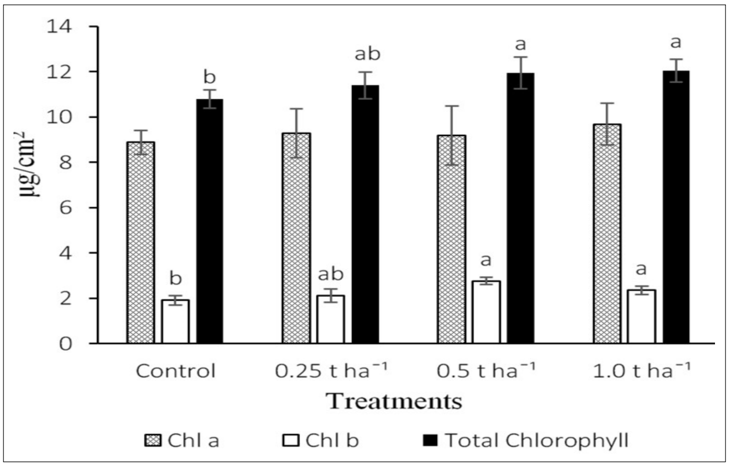

Fig 3: Chlorophyll a, chlorophyll b and total chlorophyll.

of potassium in the soil was independent of dolomite application. It might be a reason of the concentration of potassium in sesame plants was not different in all treatments with or without application of DPR.

Effects of DPR on yield components and seeds yield of sesame

Fig 5 shows that the number of pods per plant, pod weight and the number of seeds per pod were statistically significantly different at 5% among all treatments. The number of pods per plant was the highest in the plants treated with 0.5 t ha^{-1} DPR (47.0 pods per plant). Similarly, the number of seeds per pod was the highest in plants treated with 0.5 t ha^{-1} DPR (140 seeds). In this study, the weight of 1,000 seeds was not affected by the DPR application. The higher number of pods per plant might be the higher phosphate uptake in plants. According to Kashani *et al.* (2015), phosphorus is an essential nutrient for flower formation and seed production.

Fig 6 shows that the application of the DPR with an amount of 0.5 t ha^{-1} had the highest yield, with 1.61 t ha^{-1} and there was a statistically significant difference at 5% compared to the control treatment (1.29 t ha^{-1}). Significantly, the lowest seed yield was recorded in sesame plants with no DPR treatment and the yield increase rate compared to the control treatment was 24.8%. Similar to the study of Cahyono *et al*. (2022) on soybean planted on Alfisols in Jumantono, Karanganyar, Indonesia, the seed yield increased by double with the application of dolomite. There were no significant differences in sesame yield between plants fertilized with 0.5 and 1.0 t ha^{-1} DPR. The soybean yield increased when dolomite or phosphate rock was applied in a single form or in combination (Minardi *et al*., 2021).

Financial efficiency

Table 2 indicates that the profit from growing the sesame is high (above 18 million VND/ha). Adding DPR increases the cost of labor and DPR. Application of 0.5 and 1.0 t ha^{-1} DPR for sesame helped increase yield significantly higher than without application or 0.25 t ha^{-1} of DPR. However, the profit of the treatments of 0.25 and 1.0 t ha^{-1} DPR was lower than the profit of the control treatment. Application of 0.5 t ha^{-1} DPR gave a higher profit than the control treatments (4.5 million VND/ha).

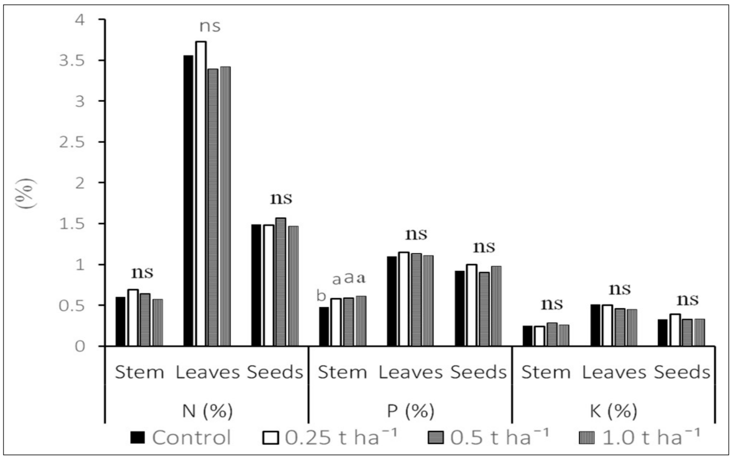

Fig 4: Nitrate, phosphate and potassium content in stem, leaves and seeds of sesame.

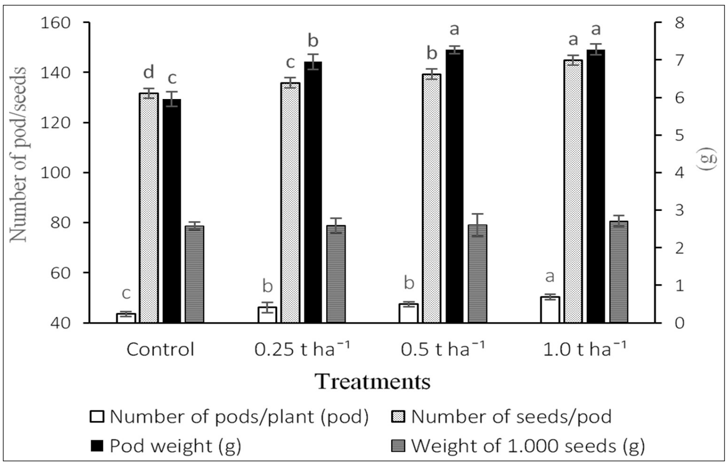

Fig 5: Number of pods/plant, number of seeds/pod, pod weight and weight of 1,000 seeds.

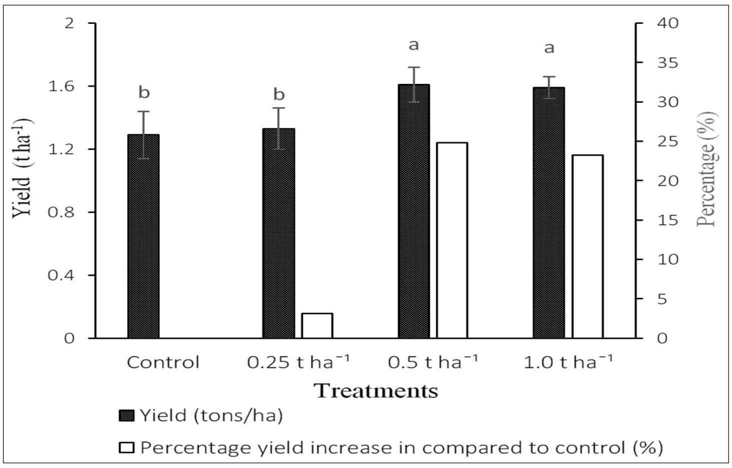

Fig 6: Seed yield and percentage yield increased compared to control on different treatments.

Table 2: The profit from different treatments of DPR (VND 1,000/ha).

Parameters	Treatments			
	Control	0.25 t ha^{-1}	0.5 t ha^{-1}	1.0 t ha^{-1}
Yield (tons/ha)	1.29	1.33	1.61	1.59
1. Total cost in 2022	13,500	15,750	17,750	21,500
- Fixed cost expanse	13,500	13,500	13,500	13,500
- Labor extra	0	500	750	1,000
- DPR application	0	1,750	3,500	7,000
2. Revenue	32,250	33,250	40,250	39,750
3. Profit (3 = 2 - 1)	18,750	18,000	23,249	18,250
4. Profit compared to control	0	- 1,250	4,499	- 500

Note: Sesame seed 25,000 VND/kg, DPR 7,000 VND/kg in 2022.

CONCLUSION

Sesame was fertilized with doses 60 N - 60 P_2O_5 - 30 K_2O kg ha^{-1} and the addition of 0.5 t ha^{-1} DPR increased plant height, number of leaves and pods per plant, total chlorophyll content in leaves, number of seeds per pod and seed yield (1.61 t ha^{-1}). The seed yield increase rate in comparison with the control treatment was 24.8%. The phosphate content increased in the stem when sesame plants were applied with DPR but not in the leaves and seeds. DPR application to paddy soil (slight acid soil) could be practiced to raise the pH of the soil (0-20 cm) and elevate $P_{Available}$ amount. The suitable application amount of DPR to sesame plants gave good financial efficiency.

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Conflict of interest: None.

REFERENCES

Bhatt, M.K., Labanya, R., Joshi, H.C. (2019). Influence of long-term chemical fertilizers and organic manures on soil fertility-A review. Universal Journal of Agricultural Research. 7(5): 177-188. DOI: 10.13189/ujar.2019.070502.

Billah, M., Khan, M., Bano, A., Nisa, S., Hussain, A., Dawar, K.M., Munir, A. and Khan N. (2020). Rock phosphate-enriched compost in combination with rhizobacteria; A cost-effective source for better soil health and wheat (*Triticum aestivum*) productivity. Agronomy. 10: 1390. Doi:10.3390/agronomy 10091390.

Brewer, D.R., Franco, J.M., Garcia-Zapateiro, L.A. (2016). Rheological properties of oil-in-water emulsions prepared with oil and protein isolates from sesame (*Sesamum indicum*). Food Science and Technology. 36(1): 64-69. DOI: 10.1590/ 1678-457X.6761.

Cahyono, O., Minardi S., Hartati, S. and Rifaldi, D. (2022). Increasing growth, seed product and phosphorus uptake efficiency of Soybean [*Glycine max* (L.) Merrill] in Alfisol using phosphorus fertilization methods. International Journal of Agricultural Technology. 18(4): 1415-1428.

Chutichude, B., Chutichudet, P., Kaewsit, S. (2010). Effects of dolomite application on plant growth, activities of polyphenol oxidase and internal quality of grand rapids lettuce. International Journal of Agricultural Research. 5: 690-707.

Damrongrak, I., Onthong, J., Songklanakarin, C.N. (2015). Effect of fertilizer and dolomite applications on growth and yield of tapping rubber trees. Songklanakarin Journal of Science and Technology. 37(6): 643-650.

FAO. (2023). Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL. Accessed: 07 June 2023.

Hellal, F., Saied, E.S., Zewainy, R., Amer, A. (2019). Importance of phosphate pock application for sustaining agricultural production in Egypt. Hellal *et al*. Bulletin of the National Research Centre. 43:11. https://doi.org/10.1186/s42269-019-0050-9.

Jayathilaka, A.K.K.R. (2020) Operating profit and net profit: Measurements of profitability. Open Access Library Journal. 7: 1-11. Doi: 10.4236/oalib.1107011.

Kashani, S.D., Buriro, M., Nadeem, A., Ahmed, N., Saeed, Z., Mohammad, R., Ahmed, S. (2015). Response of various sesame varieties under the influence of nitrogen and phosphorus doses. American Journal of Plant Sciences. 6:405-412. DOI: 10.4236/ajps.2015.62046.

Khuong, N.Q., Thuc, L.V., Tran, N.T.B., Huu, T.N., Sakagami, J.I. (2022). Foliar application of boron positively affects thegrowth, yield and oil content of sesame (*Sesamum indicum* L.). Open Agriculture. 7: 30-38. https://doi.org/10.1515/opag-2022-0067.

Kim, H.J. and Li, X. (2016). Effects of phosphorus on shoot and root growth, partitioning and phosphorus utilization efficiency in Lantana. Hortscience. 51(8): 1001-1009. DOI: 10.21273/HORTSCI.51.8.1001.

Krismawati, A., Latifah, E., Sugiono. (2022). Effectiveness of dolomite on growth and yield of maize (*Zea mays* L.) in Dry Land. Advances in Biological Sciences Research. 17: 5-20. https://doi.org/10.2991/absr.k.220102.002.

Lestari, Y., Maas, A., Purwanto, B.H., Utami, S.N.H. (2016). The influence of lime and nitrogen fertilizer on soil acidity, growth and nitrogen uptake of corn in total reclaimed potential acid sulphate soil. Journal of Agricultural Science. 8(12): 197-205. DOI:10.5539/jas.v8n12p197.

Minardi, S., Haniati, I.L., Harieni, S., Sudadi, Cahyono, O., Suryono. (2021). Effect of phosphorus and calcium availability as influenced by manure, rock phosphate and dolomite on soybean yield. Earth and Environmental Science. 828: 012012. DOI: 10.1088/1755-1315/828/1/012012.

Moran, R. (1982). Formulae for determination of chlorophyllous pigments extracted with N,N-Dimethyl formamide. Plant Physiology. 69(6): 1376-1381. DOI: 10.1104/pp.69.6.1376.

Najeeb, U., Mirza, M.Y., Jilani, G., Mubashir, A.K., Zhou, W.J. (2011). Sesame. Technological Innovations in Major World Oil Crops. 1: 131-145. DOI: 10.1007/978-1-4614-0356-2_5.

Ning, C., Gao, P., Wang, B., Lin, W., Jiang, N., Cai, K. (2017). Impacts of chemical fertilizer reduction and organic amendments supplementation on soil nutrient, enzyme activity and heavy metal content. Journal of Integrative Agriculture. 16(8): 1819-1831. DOI: 10.1016/S2095-3119(16)61476-4.

Rastija, D., Zebec, V., Rastija, M. (2014). Impacts of liming with dolomite on soil ph and phosphorus and potassium availabilities. 13th Alps-Adria Scientific Workshop. Villach, Ossiacher See, Austria.

Silber, A., Levkovitch, I., Graber, E.R. (2010). pH-dependent mineral release and surface properties of corn straw biochar. Agronomic implications. Environmental Science and Technology. 44(24): 9318-9323. https://doi.org/10.1021/es101283d.

Soeparjono, S. and Kadiyasari, I.F. (2021). The effect of lime of dolomite and NPK fertilizers on the response of growth, yield and protein content on black soybean (*Glycine soja* L. Merr) in acid soils. Earth and Environmental Science. 759: 012022. Doi:10.1088/1755-1315/759/1/012022.

Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H. (1996). Methods of Soil Analysis, Part 3: Chemical methods. Madison, Wisconsin, USA: Soil Science Society of America, Inc. DOI:10.2136/sssabookser5.3.

Suksri, A. (1998). Effects of dolomite on growth and seed yields of soybeans *(Glycine max* L.) grown on oxic paleustult soil in northeast Thailand. Pakistan Journal of Biological Sciences. 1(3): 215-218. DOI: 10.3923/pjbs.1998.215.218.

Suntoro, S., Widijanto, H., Suryono, Syamsiyah, J., Afinda, D.W., Dimasyuri, N.R., Triyas, V. (2018). Effect of cow manure and dolomite on nutrient uptake and growth of corn (*Zea mays* L.). Bulgarian Journal of Agricultural Science. 24(6): 1020-1026.

Temminghoff, E.E.J.M. and Houba, V.J.G. (2004). Plant Analysis Procedures. 2nd Edn., Springer Netherlands, Germany, ISBN-13 978-90-481-6717-3.

Uygur, V. and Şen, M. (2018). The effect of phosphorus application on nutrient uptake and translocation in wheat cultivars. International Journal of Agriculture, Forestry and Life Science. 2(2): 171-179.

Wang, L., Yu, S., Tong, C., Zhao, Y., Liu, Y., Song, C., Zhang, Y., Zhang, S., Wang, Y., Hua, W. *et al.* (2014). Genome sequencing of the high oil crop sesame provides insight into oil biosynthesis. Genome Biology. 15(R39): 1-13 http://genomebiology.com/2014/15/2/R39.

Wei, P., Zhao, F., Wang, Z., Wang, Q., Chai, X., Hou, G., Meng, Q. (2022). Sesame (*Sesamum indicum* L.): A comprehensive review of nutritional value, phytochemical composition, health benefits, development of food and industrial applications. Nutrients. 14: 4079. https://doi.org/10.3390/nu14194079.

Yang, Y., Zhenli, H., Yang, X., Fan, J., Stoffella, P., Brittain, C. (2012). Dolomite phosphate rock–based slow-release fertilizer for agriculture and landscapes. Communications in Soil Science and Plant Analysis. 43: 1344-1362. DOI: 10.1080/00103624.2012.666308.

Zheng, H., Wang, Z., Deng, X., Zhao, J., Luo, Y., Novak, J., Herbert, S., Xing, B. (2013). Characteristics and nutrient values of biochars produced from giant reed at different temperatures. Bioresource Technology. 130: 463-471. https://doi.org/10.1016/j.biortech.2012.12.044.