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Remediating the Degraded Land Due to Mining of Pumice Stone in the Northern Part of Lombok Island by Applying Silicate Rock-Organic Fertilizer Priyono1, J., C. K. Rahardjo1 & A. A. Rahmianna2 1 Center for Research and Development of Tropical Dryland, University of Mataram Jalan Pendidikan 37 Mataram 831250 NTB, Indonesia. 2 Indonesian Legumes and Tuber Crops Research Institute Jalan Raya Kendalpayak Km 8 Malang 65101- East Java, Indonesia. Abstract The research was aimed to identify effects of the application of a remediating agent which was a mixture of ground basaltic-silicate rock powder with manure, termed as silicate rock-organic fertilizer (SROF), on soil quality of the degraded land due to mining of pumice stone in the northern part of Lombok Island. The degraded land was physiographically fixed, manually cultivated, and terraced accordingly to the land sloping. A completely randomized block design was applied with a treatment of 5 application rates of the remediating agent (0 – 10 t.ha-). A week after application of the remediating agent, corn (var. BISI 2) was grown on the land. Soil organism-respiration rate was measured at 45 and 90 days after planting, and several soil chemical properties were identified after crop harvesting. Results indicated that application of the remediating agent (SROF) significantly increased soil organism activity, soil cation exchange capacity, growth and yield of corn. It was concluded that the mixture of basaltic-silicate rock powder and manure may be used as an effective remediating agent to rebuild the physically, chemically as well as biologically degraded land due to mining. Keywords: ameliorant, silicate rock, degraded land, remediation, pumice stone Introduction Mining of pumice stone in Northern Lombok – NTB, Indonesia, has destroyed hectares of farming land in the area. To rebuild the degraded land requires effective method and materials. Based on the local condition, it was proposed that basaltic rocks and organic matter (manure) – the environmentally sound and locally available materials may be used as the most appropriate remediating agent. The finely ground basaltic rocks or silicate rock fertilizer (SRF) has been known to have multi functions, e.g., as a source of almost all nutrients essential for plants (except N) or multinutrient fertilizer and a general soil ameliorant (Priyono, 2005). Another well known natural material having multi functions similarly to SRFs is organic matter or manure. A numbers of researchers showed that the application of SRFs increased pH of acidic soils (Holdren and Berner, 1979; Gillman, 1980; Gillman et al., 2001 and 2002; Leonardos et al., 1987 and 2000; Wang et al., 2000; Coventry et al., 2001; Harley, 2002; Priyono et al., 2002; Priyono et al., 2007), cation exchange capacity ( Gillman et al., 2001 and 2002; Coventry et al., 2001), and reduced Al-toxicity effects and P adsorption by polyvalent cations (Mn, Fe, Al) in acidic soils (Coventry et al., 2001). The application of SRFs also increased organism activity in acidic to neutral soils (Priyono et al., 2007) and reduced salt effects of saline-sodic soils on plant growth (Sumarlin, 2008). Another potentially beneficial effect of using SRF was associated to its high content of Si, i.e., 4 – 8 % Si extractable in 0.01M citric- oxalic acid (Priyono and Gilkes, 2008a). Results of a greenhouse experiment (Priyono and Gilkes, 2008b) indicated that the application of SRFs equivalent to 5 – 10 t.ha- increased 2 – 4 fold of the uptake of Si by ryegrass. The other proves were that applying Si-high containing fertilizers on several crops, mainly grasses increased the tolerance of the crops to pathogen attacks (Volk et al., 1958; Epstein, 1999) and reduced the toxicity effects of Al on corn (Corrales et al., 1997). Based on above findings, it was presumed that the application of a mixture of SRF and manure, termed as silicate rock-organic fertilizer (SROF), had more effective effects in improving soil properties being suitable for plant growth than those materials were applied individually. Dissolution of plant nutrients from SRF was accelerated by the present of organic acid (Priyatna et al., 2007) or organic matter (Priyono et al., 2007 ), while the decomposition of organic matter that produced organic acids were speed up by adding SRF. Therefore, SROF was proposed to be the cheap, effective, and environmentally sound material to rebuild the physically, chemically, and biologically degraded land due to mining. The objectives of the research were to identify effects of application rate of SROF on soil quality as indicated by soil biological activity (respiration rate) and chemical properties, growth and yield of crop (corn). Materials and Methods Land Preparation The research was carried out in Akar-Akar Village, in the northern part of Lombok Island, Indonesia from May to August 2009. The degraded land (0.5 ha) was prepared for the experiment by fixing its physiographical condition, i.e., by manual smoothening, cultivating (by using a hand tractor), and then terracing accordingly to land sloping. The terraces were functioned as border line of the experimental blocks. Each block was divided into 5 experimental plots of 25 m x 13 m each. Among the plots were separated by 50cm-width and 30cm-height border lines. The general condition of the degraded land and that after being smoothen and terraced are shown in Figure 1. General figure of the degraded land Smoothening and terracing the land Figure 1. General condition of the degraded land in the northern part of Lombok Island (left) and the land after being smoothen and terraced (right) A sprinkle irrigation system was prepared for watering in this experiment by utilizing a deep-ground water wheel of 80m depth. Water was pumped from the wheel at rates of 18 - 20 L.s-. A sprinkle outlet was set in each experimental plot by connecting the PVC pipes to the main water line and then to the water pump. Preparing Remediating Agent Basaltic-silicate rocks – the quarry by product (Ø < 1 cm) was ground by using an attrition ball mill. The rock material (2 kg) and 5 kg of stainless steel balls (Ø = 22 mm) were put into a ball mill vial having capacity of 18.8 L. The mill was operated at speed of about 150 rpm for 30 minutes. This milling procedure was run several times to have enough amount of rock powder for this experiment. Chemical and mineral compositions of the rock powder are presented in Table 1. To provide a remediating agents (SROF), the rock powder was mixed with dry composted cattle wastes (manure) at a ratio of rock powder/manure = 1/4. Experimental Design A completely randomized block design consisting of 3 blocks was applied with a treatment of the application rates of SROF (0, 2.5, 5, 7.5, and 10 t.ha -). SROF was evenly applied into about 5-cm depth of planting rows and were covered with soil, moisten and maintained at field capacity for a week. Corn (var. BISI 2) was planted 1 seed per planting Table 1. Chemical and mineral compositions of rock powder used in this experiment Main elements $SiO_2$ $Al_2O_3$ CaO MgO $K_2O$ $Na_2O$ FeO MnO ZnO CuO others (% oxide) * 52.3 24.8 4.8 1.8 6.3 3.3 6.2 0.15 0.01 0.33 < 0.01 Main minerals ** Gendrite; Fargasite; Albite; Anorthite; Muscovite Particle size (μm) < 10 10–20 20-30 30-40 40–60 60–80 > 80 Proportion (%) *** 28 5 5 6 8 8 40 * Wet destruction by using HF (modified Jackson, 1956). ** Interpreted from XRD (X-ray diffraction) patterns. *** Pipette method (modified Gee and Bauder, 1986). hole in the plant spacing of 20 cm x 80 cm. Basal fertilizers consisting of N and P in forms of urea (138 kg N.ha-) and superphosphate-18 (27 kg $P_2O_5$. ha-) were applied. Crop watering by using sprinkle irrigation system was carried out in each 3 – 4 days, depending on soil moisture condition and growing stage of the crop. Weeding was carried out twice at 21 and 45 days after planting (d.a.p), and harvesting was in 97 d.a.p. The observed parameters in this experiment were (1) respiration rate of soil organism, (2) several chemical properties of residual soil (after harvesting), (3) weight of dry matter crop, and (4) yield of corn. The respiration rate of soil organism as an indicator of general soil quality was measured directly in field condition at 45 and 90 d.a.p. The measurement was carried out on 6 points in each plot. A day before measurement, soil was watered to field capacity. A 20cm-lenght of top-covered PVC pipe (Ø = 5 inches) was inserted into the ground up to 10cm-depth. The gas of $CO_2$ produced from soil organism respiration processes in 24 hours was collected by flowing the gas through a plastic line (Ø = 5 mm) into a plastic bottle containing 0.1N KOH, and then the quantity of $CO_2$ was measured with acid-base titration method (using 0.01N HCl). Several chemical properties of soils in initial state (before planting corn) and those for residual soils (after harvesting) were identified. Soil acidity ($pH_{H_2O}$ 1 : 2,5) was measured by using pH-meter, total C-organic by using dichromate oxidation (Walkey and Black, 1935), N total with Kjedahl, and extractable P with Bray II methods. Cation exchange capacity (CEC) of soil was measured by using a buffer solution of 1N ammonium acetate pH 7, and concentration of the exchangeable basic cations (Na, Ca, Mg, and K) in the filtrates of the extraction was measured with AAS. Results and Discussion Respiration Rates Statistically, the application rate of SROF significantly increased soil organism activities (respiration rate). The relationships between respiration rate and application rate of SROF are presented in forms of linear regression in Figure 2. 140 45 d.a.p Respiration rate (me CO2.m-3.h-) 120 100 80 60 40 20 0 90 d .a.p 45 d.a.p: R Rate (me CO2.m-3.h-) = 86.4 + 3.12 SROF (t. ha-), R2 = 0.90* 90 d.a.p: R Rate (me CO2.m-3.h-) = 39.2 + 6.64 SROF (t.ha-), R2 = 0.96* 0.0 2.5 5.0 7.5 10.0 Application rate of SROF (t.ha-) Figure 2. The Relationship between the application rate of silicate rock-organic fertilizer (SROF) and the average of respiration rate at 45 and 90 days after planting (d.a.p). As shown in Figure 2, the respiration rate at 45 d.a.p. is higher than for that of at 90 d.a.p. However, the intensity effect SROF application to the respiration rate at 45 d.a.p. was lower than for that at 90 d.a.p. Based on the regression equations, each adding 1 t.ha- of SROF increased the respiration rate up to about 3.12 me CO2.m-3.h- for the measurement at 45 d.a.p. and about 6.64 me CO2/m3/hour for the measurement at 90 d.a.p. Clearly, remediation in relatively short period by using SROF up to 10 t.ha- significantly improved soil quality of the degraded. Changes of Soil Chemical Properties Several chemical properties of soils at initial condition were compared to those after corn harvesting (Table 2). As shown in Table 2, clear changes of soil properties due to the application of SROF were the increases of soil C-organic content and CEC, while soil pH and exchangeable cations tend to decrease. The increase of C-organic content could be due to the direct effect of adding SROF as well as root exudates of the crop, which the increases of both constituents in soil may contribute to the increase of soil CEC. Table 2. Several chemical properties of soils before remediation and after corn harvesting No Soil Properties Unit Initial Application Rate of SROF (t.ha-) Condition 0 2.5 5.0 7.5 10 1. pHH2O (1:2.5) 2. C-organic 3. N-total 4. Extr.-P 5. CEC 6. Exch. Ca 7. Exch. Mg 8. Exch. K - % mg.kg- % cmolc.kg- cmolc.kg- cmolc.kg- cmolc.kg- 5.86 5.60 0.20 0.34 0.02 0.01 2.80 3.20 4.50 4.80 3.80 4.20 0.70 0.66 0.56 0.41 5.53 5.61 0.42 0.26 0.02 0.02 4.10 6.40 5.20 5.26 3.74 3.34 0.52 0.31 0.48 0.62 5.48 0.51 0.01 4.80 5.55 2.93 0.43 0.22 5.56 0.44 0.01 2.80 6.06 2.23 0.62 0.32 If the direct effect of root exudates on CEC was ignored, each adding 1 t.ha- of SROF will increase CEC up to about 0.6 cmolc.kg-. Practically, the increase of CEC has important meaning in association to the general soil properties in Northern Lombok, e.g., coarse-sandy textured and porous, which adding SROF may reduce plant nutrient loss from the soil due to leaching, mainly during the rainy season. Corn Growth and Yield The average weights of dry biomass, yield, and 1000 seeds are presented in Table 3. Statistically, the application rate of SROF significantly increased those three crop components. As shown in Table 3, the average of dry biomass was nearly doubled due to adding SROF of 10 t.h-, e.g., from 2.46 to 4.06 t.h-. Total yield and weight of 1000 seeds each was increased about 40 %, e.g., from 0.95 to 1.41 t.h- for yield and 216.6 to 246.7 g for weight of 1000 seeds. Clearly, the application of SROF increased corn growth, quantity and quality of corn yield. Although the total yield of corn (var. BISI-2) in this experiment was very low (< 2 t.ha-) relative to the potential yield of the corn variety (7 – 8 t.h-), the application of SROF significantly improved the productivity of the land. To restore the degraded land into highly productive land may be need 3 – 4 times of SROF application into the soils. Table 3. The average weights of dry biomass, yield, and of 1000 seeds of corn Ratec of SROF Dry Biomass Yield 1000 Seeds ……………….. (t.ha-) ………………….. ……. (g) ……. 0.0 2.46 a 0.95 a 216.6 a 2.5 3.38 b 1.28 b 223.3 b 5.0 3.36 b 1.26 b 236.7 c 7.5 4.06 c 1.38 b 246.7 d 10.0 5.02 d 1.41 b 246.7 d Note: values in the same column followed by the same letter were not significantly different based on the test of LSDα = 0.05. Conclusion The application of a mixture of basaltic rock powder and manure (SROF) up to 10 t.ha- significantly increased soil quality and productivity of the degraded land due to mining of pumice stone (soil parent material) in Northern Lombok – NTB. The mixture (SROF) may be used as an effective and locally available remediating agent to rebuild the physically, chemically, and biologically degraded lands. Acknowledgement This reasech was funded by The Central for Agricultural Research (Balitbang Pertanian Pusat) through the KKP3T scheme 2009. 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