Soil toxic elements evaluation and implementation of apple rejuvenation technology on dry land in Batu, East Java

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Abstract. Apple is subtropical plant that well adapted in several regions in Indonesia. One of them is Batu city in East Java province. Nowadays, Batu city has a problem due to decreasing of apple area land, more than 16 % in the last decade. There are many factors, two of them are plant age and soil condition. Therefore, it was required a research to evaluate soil chemistry and implement apple rejuvenation technology on dry land. This research was conducted from May to December 2015 at five apple areas; Bumiaji, Tulungrejo, Sumbergondo, Punten and Bulukerto. A survey method was done to address first purpose. Soil sample was taken by purposive sampling method and was analyzed in laboratory to measure soil characteristics. Laboratory analysis showed soil metal content very low and under critical value. However, soil pH and organic matter content were not under ideal condition, strong to medium acid and 30 % of area were low organic content (< 2%). Second studied was implementation apple rejuvenation technologies on dry land; high quality seed, simple drip irrigation and soil amelioration.

1. Introduction
Apple is subtropical plant that well adapted in Indonesia. It is a fruit commodity that has been profitable in Indonesia since 1960. In subtropical area, the appearance of flowers due to autumn season. Therefore, technology discovery about apple flowering in tropical region was the main factor that support developing apple area. The key technologies to induce flowering are bending and leaf cutting, and supported by low temperature.

There are many apple development area in Indonesia, the widest area is East Java province (Batu, Malang and Pasuruan district). In Batu, recently apple plant population decrease significantly, 16 % tighter than a decade ago [1].There are many aspects that cause land of apple decreasing. The main aspects are socio-economic, environments and cultivation. Socio-economic relate to labor availability and production profits. Environmental factors include climate components, mainly temperature and rainfall. Cultivation aspect relate to orchard management, such as; fertilization, irrigation and pest protection.

This research focused on cultivation aspect, mainly land degradation because of chemical utilization, such as pesticide and fertilizer. The utilization of chemicals continuously for a long time period results in environmental damage. Farmers in batu cultivate apple plants intensively, use large amounts of fertilizers and pesticides. Therefore, it requires evaluation to know soil condition recently.

Rejuvenation technology means a technological package for planting apples corresponding with soil conditions. Apple rejuvenation is important to do because plant age average more than 20 years
old and the production decreased. It requires some technologies to support a success of rejuvenation. Seed quality, land preparation and irrigation are the main requirements to generate health plant. Indonesian Agency for Agricultural Research and Development (IAARD) has released technologies about its, thus it’s time to implement it.

2. Materials and Methods
This research was conducted from May to December 2015 at five apple areas; Bumiaji, Tulungrejo, Sumbergondo, Punten and Bulukerto. These areas are the central of apple plant in Batu. It was divided in two activities, first was survey on apple area to evaluate soil chemistry in existing area and second was implementing rejuvenation technology as pilot project for farmers in the surrounding area. The method of first activity was description analysis from the soil samples. Soil sample was taken with purposive sampling in the old apple trees, above 20 years. In other hand, second activity also took soil sample on the bare land that would be planted as rejuvenation.

Soil properties analyzed in this study were texture, soil chemical and heavy metal content. The parameters of the soil chemical properties analyzed were pH, C-Organic, CEC (Cation Exchange Capacity), N, P, K, Cu and Mg concentration in soil. Heavy metal properties were Pb, Cd, Co, Cr, Ni, As and Hg. The results of heavy metals analysis to address first purpose, is the apple area decreasing because of soil toxic. However, second activity only analyzed soil chemistry and texture. The results of soil analysis in the second activity were used as recommendations for rejuvenation of apple plants.

Soil texture was analyzed according to soil textural triangle [2]. Soil pH was determined in distilled water in a solid–liquid (S/L) ratio of 1: 2.5 ml/g, Organic matter (OM) content was determined by dichromate digestion based on Walkley–Black method [3]. The total cation exchange capacity of the sorptive complex (CEC) was calculated as a sum of hydrolytic acidity and total exchange bases [4]. The traditional pipette method was used for particle size analysis [5]. Once the organic matter had been removed, the remaining mineral sample was weighted and subjected to particle size analysis in order to determine the following fractions: coarse sand (0.2–2 mm), fine sand (0.05–0.2 mm), silt (0.002–0.05 mm) and clay (<0.002 mm). The radioactivity of each sample was determined by gamma spectrometry. All samples were measured for 17 h. Details on gamma lines used can be found in our previous papers [6, 7]. Total content of heavy metals in soils was determined by atomic absorption spectrometry after digestion of previously dried, ground and sieved soil samples in aqua regia [8]. Standard metal solutions used for the determination were CertiPur solutions obtained from Merck.

The number of rejuvenation plants were 400 trees per group, and total 2,000 trees or around 2 hectares have been planted. The activity begins with a survey to determine the location of the rejuvenation, then the initial soil sampling to analyze soil fertility. The implementation of IAARD innovations in tillage is by dig a hole in accordance with the recommended size (60X60X60 cm) and giving organic fertilizer as much as 20 kg / hole + 1 kg ameliorant (zeolite). The planting hole was left at least a week then prepare organic fertilizer and ameliorant (zeolite) next to the planting hole. 20 kg organic fertilizer mixed with ameliorant (zeolite) 1 kg and incubated for at least 2 weeks. After incubation was complete, a mixture of organic fertilizer and zeolite was mixed with soil and put in a 75% planting hole. After that the apple plant seeds were inserted by first removing the poly bag. After the seeds were added, the remaining mixture of soil, organic fertilizer and zeolite was inserted into the planting hole.

Making planting holes was intended so that the organisms in the soil that harm the plant can die and increase aeration and drainage in the soil so that root development can be optimal. Giving organic fertilizer is intended to improve soil physical properties, provide macro and micro nutrients, and hold water in the soil. While ameliorants are fixing materials that can improve the physical and chemical properties of the soil. Ameliorants can be organic or inorganic materials. The ameliorant used in this study is zeolite.
3. Results and Discussion

3.1. Soil chemistry assessment on existing area

Apple area in Batu decreases every year, this is predicted to be one of causes by land degradation due to intensive land use for crop cultivation. To prove this, this study conducted a survey at the central apple location and carried out soil analysis, including C-organic, CEC (cation exchange capacity) and heavy metals (Pb, Cd, Co, Cr, Ni, As and Hg). Soil sampling was taken at the location of apple plant that was old but still in optimal condition, because in these conditions intensive cultivation has been carried out for a long time, so that it was predicted to have resulted in soil conditions in that location. Each village was taken randomly by two soil samples.

Contamination and pollution of heavy metals is one of the processes that cause degradation of soil resources which can lead to decreased quality and ecological functions of the soil. Natural sources of heavy metals in the soil can come from the parent-forming material [3]. Anthropogenic sources of heavy metals in soil and environment, including; (1) metal mineral mining and smelting, (2) agricultural and horticultural materials, (3) sewage sludge, (4) burning fossil fuels, (5) metal industry (manufacturing, use and disposal of metal commodity wastes), (6) electronics (manufacturing, use and disposal of electronic commodity waste), (7) other chemical and manufacturing industries, and (8) waste disposal [9].

| Sample Code | C-organic | CEC | Heavy metal |
|-------------|-----------|-----|-------------|
|             | Walkey Black | Ekstrak NH4OAc pH 7 | Ekstrak HNO3+HClO4 |
|             | %          | cmol(+) kg⁻¹ | ppm | ppb |
| SG1         | 1.86       | 16.74 | 1.83 | 0.20 | 1.88 | 2.41 | 1.17 | 0.69 | 130,15 |
| SG2         | 2.95       | 21.55 | 1.79 | 0.20 | 1.86 | 2.46 | 1.19 | 0.78 | 31,29 |
| TR1         | 3.94       | 18.94 | 1.80 | 0.20 | 1.77 | 2.16 | 1.32 | 1.21 | < 25 ppb |
| TR2         | 3.58       | 24.55 | 1.16 | 0.13 | 1.10 | 1.51 | 0.73 | 0.58 | < 25 ppb |
| GP1         | 2.54       | 22.32 | 1.66 | 0.16 | 1.80 | 2.06 | 1.14 | 0.88 | 39,88 |
| GP2         | 2.62       | 21.57 | 1.56 | 0.18 | 1.60 | 2.33 | 1.11 | 0.74 | < 25 ppb |
| PT1         | 2.30       | 28.77 | 1.67 | 0.19 | 1.91 | 2.24 | 1.14 | 0.89 | < 25 ppb |
| PT2         | 1.90       | 20.80 | 1.38 | 0.15 | 1.38 | 1.39 | 0.83 | 0.44 | < 25 ppb |
| BJ1         | 3.25       | 23.16 | 1.53 | 0.17 | 2.09 | 4.86 | 1.37 | 1.28 | 35,35 |
| BJ2         | 3.11       | 20.73 | 1.46 | 0.17 | 2.00 | 2.02 | 1.23 | 0.72 | < 25 ppb |

Note: SG = Sumbergondo, TR = Tulungrejo, GP = Giripurno, PT = Punten, BJ = Bumiaji

The results of analysis of heavy metal content in apple centers (Table 1) show that the heavy metal content for all parameters is still below the critical limit. This means that the use of agricultural materials in apple cultivation has not caused heavy metal contamination on the ground. However, excessive and continuous use of chemicals in agricultural chemistry is feared to result in the accumulation of heavy metals on the ground so that their use needs to be reduced. Based on table 1, it is also known that C-organic content and soil CEC in apple centers vary. More than 60% of locations have an C-organic content of at least 2%. It must be maintained that the organic C content is above 2% by providing organic materials on a regular basis and those underneath it must be given high-dose, sustainable organic ingredients. Musthofa stated in his research stated that the content of organic matter in the form of C-organic in the soil must be maintained not less than 2 percent, so that the
content of organic matter does not decrease with time due to the decomposition process of mineralization every year [10].

The organic matter content is very closely related to CEC (Cation Exchange Capacity) and can increase soil CEC. The higher the content of organic matter in the soil, the higher the CEC. Cation exchange capacity (CEC) is a chemical property that is closely related to soil fertility. Soils with high organic matter or clay content have higher CEC than soils with low organic matter or sandy soils [11]. Soil organic matter content played a fundamental role in the control of Pb sorption by soils [12].

From the description above, it can be concluded that the heavy metal content in the downtown of Batu city was still below the critical threshold and less than 40% of locations have a low fertility rate based on the C-organic content and the CEC of the soil. Therefore, in locations where fertility is low it is necessary to add ameliorant materials with high and continuous doses, while in fertile locations it is also necessary to add organic matter to maintain of C-organic content more than 2%.

3.2 Soil fertility on rejuvenation land

Soil types in the location are andisol and alfisol. Darmawijaya reported andisol is soil that has characteristics dark black colour, very porous, high organic matter and amorphous clay, especially allophane and a little silica, alumina or iron-hydroxide. The land formed from volcanic ash is generally found in highland areas (> 400 m above sea level) [13]. Whereas alfisol is a type of soil formed in areas with rainfall of around 2000 to 4000 mm each year, smaller dry months of three months and climate types A, B (Schmidt / Ferguson). In Indonesia, Latosol is generally found in volcanic parent materials in the form of volcanic tuffs and igneous rocks in wet tropical regions, spread in areas with elevations between 10 - 1000 meters with rainfall between 2000 - 7000 mm per year and dry months <3 months, found in choppy to mountainous topography, with the main vegetation is dense tropical forest [14].

Soil analyzes was conducted on rejuvenation land to know the fertility before planting apple. The results of the analysis are presented in the Table 2. According to the table, there were different proportion of soil texture parts, the sand is dominant means the water easily lost from the soil through evaporation and run off. However, the soil is easier to cultivate. It was found in Sumbergondo. This is in contrast to the dominant clay, which has water holding capacity higher but more difficult to cultivate. The addition of organic matter increases the ability of soil to hold the water. Tulungrejo has this characteristic. The addition of organic matter solve this problems, improves water holding capacity and soil aeration.

Table 2. Soil characteristics on rejuvenation land.

| Parameter     | Bumiaji | Bulukerto | Punten | Tulungrejo | Sumbergondo |
|---------------|---------|-----------|--------|------------|-------------|
| pH H2O        | 5.3     | 5.1       | 5.7    | 5.9        | 5.4         |
| N total (%)   | 0.20    | 0.21      | 0.13   | 0.41       | 0.15        |
| P.total (mg kg⁻¹) | 589     | 2193      | 704    | 1116       | 704         |
| P.Bray1 (mg kg⁻¹) | 18.36   | 96.32     | 19.60  | 23.42      | 39.19       |
| K.total (mg kg⁻¹) | 955     | 1123      | 470    | 800        | 660         |
| K (me/100g)   | 1.64    | 1.90      | 0.46   | 0.87       | 0.86        |
| Ca (me/100g)  | 9.86    | 10.49     | 10.67  | 7.58       | 7.48        |
| Mg (me/100g)  | 1.29    | 0.64      | 1.91   | 1.15       | 0.96        |
| CEC (me/100g) | 28.95   | 31.53     | 24.46  | 32.71      | 22.41       |
| Texture       | Silty Clays | Loam  | Clay loam | Clay | Sandy loam |
| Sand (%)      | 15      | 26        | 20     | 36         | 70          |
| Silt (%)      | 56      | 48        | 52     | 23         | 15          |
| Clay (%)      | 29      | 26        | 28     | 41         | 15          |
Based on the Table 2, there were two levels of soil pH; strongly acid (<5.5) at Bumiaji, Bulukerto and Sumbergondo, moreover another places were medium acid (5.5-6.0). Soil pH plays key role on nutrient availability, more acidic results in the smaller macro nutrients available. The optimum soil pH for nutrients availability is very slightly acid (6.5-7.0). Therefore, the soil requires the addition of lime to increase soil pH. The addition of lime also improve calcium and magnesium content of soil, which are low and medium based on soil analysis. In general, phosphorus available content lower than total because of P fixation. It can be released by ameliorant addition. The use of ameliorant material in the form of zeolite, compost and a combination of compost and zeolite can improve the properties of sand soil such as pH, organic-C, available-P and CEC, where the combination of compost and zeolite treatment as ameliorant material can improve soil chemical properties of sand with an increase in soil pH, organic-C, and P even though the increase was not significant, while there was no significant effect on land CEC [15].

3.3. Apple rejuvenation technology implementation

Application of rejuvenation technology for apple plantations using technological innovations produced by Indonesian Agency for Agricultural Research and Development (IAARD) was applied to five different locations / villages, namely Bulukerto, Punten, Bumiaji, Tulungrejo, and Sumbergondo. Rejuvenation was conducted in the apple farmer group area which was the smallest scale of counseling. The technological innovations that have been implemented include: (1) Use of quality apple seeds in accordance with regulations on the supply of quality seeds produced by IAARD with a single clonal system; (2) Preparation of apple rejuvenation land management with environmentally friendly technology using recommended organic fertilizer 20 kg + 1 kg ameliorant / tree given to planting holes size 60 x 60 x 60 cm; (3) Water saving technology use simple drip irrigation.

Zeolites which have functions include: returning lost soil nutrients, storing and binding elements needed both macro and micro nutrients so that they remain available, loosening the soil, because zeolites have large pores so that circulation oxygen is good for plant roots, saves the use of fertilizer (not wasted), because it is bound by zeolite, absorbs heavy metals and elements that interfere with plant growth [16].

Planting apple plants in each location varies depending on the condition of the availability of water. Planting carried out in the first stage is the location of land where sufficient water is available, carried
out in the dry season, namely in August - September. Observations on plant growth were carried out in October - November 2015. Data on plant growth in each location were presented in Table 3.

Apple tree was planted on dry season in five areas; Bulukerto, Punten, Bumiaji, Sumbergondo and Tulungrejo. Growth parameters were observed: rootstock diameter, scion diameter, plant height and scion height. Table 3 showed that until the end of November 2015, the lowest growth parameter was Sumbergondo. It was caused by Cation Exchange Capacity (CEC) lowest (Table 2). Ameliorant addition can increase CEC value, however it requires time to chemical reaction.

Table 3. Effect rejuvenation technology on apple growth

| Area       | $\phi$Rootstock (mm) | $\phi$Scions (mm) | Plant height (cm) | Scion height (cm) | Bud Number |
|------------|----------------------|-------------------|-------------------|-------------------|------------|
| Bulukerto  | 13.71                | 8.47              | 126.20            | 109.10            | -          |
| Punten     | 12.79                | 8.91              | 121.80            | 109.00            | -          |
| Bumiaji    | 15.61                | 10.56             | 143.80            | 133.10            | -          |
| Sumbergondo| 12.26                | 7.77              | 86.40             | 71.20             | 3.80       |
| Tulungrejo | 20.11                | 13.68             | 98.60             | 90.50             | 2.00       |

Table 4. Growth apple performance on different irrigation systems

| Irrigation systems | $\phi$Rootstock (mm) | $\phi$Scions (mm) | Plant height (cm) | Scion height (cm) | Bud Number |
|--------------------|----------------------|-------------------|-------------------|-------------------|------------|
| Sumbergondo        |                      |                   |                   |                   |            |
| Drip irrigation    | 13.05                | 7.37              | 73.20             | 62.70             | 2.90       |
| Conventional       | 12.26                | 7.77              | 86.40             | 71.20             | 3.80       |
| Bumiaji            |                      |                   |                   |                   |            |
| Drip irrigation    | 15.21                | 11.05             | 143.80            | 134.00            | -          |
| Conventional       | 15.61                | 10.56             | 143.80            | 133.10            | -          |

Figure 2. Irrigation systems on dry season, conventional (a) and simple drip irrigation (b)
The disadvantage of starting an apple planting in the dry season is the lack of water. Even though there was water that can be used for irrigation during the dry season, it will require additional costs or energy for watering everyday. To anticipate this problem, in addition to conventional watering, it is also carried out using simple drip irrigation which uses easily available materials and does not require high costs. This simple drip irrigation system was conducted in two places, Sumbergondo and Bumiaji. The comparison of the results of apple plant growth using these two systems can be seen in table 4. The growth of apple plants that use a drip irrigation system and conventional showed similar performance.

4. Conclusion
Heavy metal content in the soil of apple area below the critical threshold. Therefore, it was not the cause of apple area decreasing. Forty percent of existing apple land have a low fertility rate based on the C-organic content and the CEC of the soil. Therefore, it is necessary to add ameliorant materials with high and continuous doses to maintain of C-organic content more than 2%. The technology applied to apple rejuvenation is expected to be adopted by farmers.

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