Rehabilitation of Open Cut Coal Mine with Paper Mulberry (Broussonetia Papyrifera) in Indonesia

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Summary

Most of the coal is produced from open cut mining in Indonesia. In recent years, Indonesian coal companies are increasing coal production and developing new coal mines in order to accommodate the heavy demand for coal all over the world. However, mining operation of open cut mines gives serious impacts on surrounding environment. Therefore, an appropriate rehabilitation program has to be taken into consideration when the mine plan is designed. The basic concept of rehabilitation in open cut mines is the creation of a stable and self-sustaining land surface in post mine surface involved the creation of conditions suitable for the establishment and permanent development of a dense cover of vegetation. Additionally, the utilization of these lands as other potential economic and use options become to be considered recently. It can be thought that Paper Mulberry is one of efficient species to plant rehabilitation area. This species is a fast growing tree and can grow under warm temperature, subtropical and tropical regions, and various soil conditions. There are a lot of usages in paper mulberry such as making paper, clothing items, and medicine. In this study, application of Paper Mulberry which has two characteristics, fast growing tree and productive use in the disturbed area, was discussed by means of several laboratory and field tests. It was found that 1) hot-water treatment in 80°C for 10 seconds is most effective treatment to improve germination rate (more than 80%), 2) Paper Mulberry can grow up under the rehabilitation area in Indonesian open cut mine and the management term of seedlings in Nursery can be simplified by transplant to the field early though the competition with cover crop has to be taken into consideration, 3) appropriate management of soil texture in the field can promote the growth rate of this species in terms of fiber resources.

Keywords: hot-water treatment, open cut mine, paper mulberry, rehabilitation, soil management

Introduction

Indonesia is the second largest coal exporter to Japan, accounting for 30 Mt/year. Almost all of clean coal is produced from open cut mining in Indonesia. As the demand of coal not only in Indonesia but also in the rest of the world is increased dramatically due to increasing the energy supply in the world, the development of coal mining is advanced in order to meet the demand of coal. However, a mining operation of open cut mines has some disadvantages for surrounding environment such as disturbance of the tropical rainforest, the pollution of surface and/or ground water, and erosion. Therefore, adequate rehabilitation program should be conducted as soon after the surface mining operation has finished in order to minimize these environmental impacts and recover the nature and ecosystem.

The primary purpose of rehabilitation in post mine area is the recovery of the nature and ecosystem, and the creation of a self-sustaining land surface. However, the effective utilizations of post mine area for the productive uses such as agricultural crops and other potential economic (Figure 1) have been taken into consideration in recent years (Hargraves and Martin, 1993). In this research, Paper Mulberry is focused as one of the plants which are expected to be productive use in post mine area. This species is fast growing tree and can grow under warm temperature, subtropical and tropical regions, and various soil conditions. Therefore, it can be said that paper mulberry has wide range of application and potential to apply in post mine area. Moreover, there are a lot of usages in paper mulberry such as making paper, clothing items, and medicine. If paper mulberry can be applied in post mine area, the fibre resources can be provided continually instead of coal resources from this area not just revegetation (Hamanaka et al, 2011).

This paper discusses the applicability of Paper Mulberry in post mine area in Indonesia by means of several laboratory and field tests.

Paper Mulberry

Paper Mulberry is deciduous and soft woody tree, which can grow up to 12-35m in height. The bark is thick, contains milky sap, and small conical buds. The leaves are broadly, jagged, hairy and roughly, especially lower surface (Arthur, 2006). Fruit are sweet and edible with diameter of

Fig. 1 Utilization of rehabilitation area: (a) Cow husbandry, (b) Recreation area, (c) Cultivate oil of palm

Rys. 1 Wykorzystanie obszaru rekultywacji: (a) hodowla krów, (b) teren rekreacyjny, (c) uprawa palm

Fig. 2 Paper Mulberry

Rys. 2 Papier z morwy

1-3 cm consist of light-red hair. The fruits contain 200-350 small hard dark-red seeds (Figure 2).

Paper Mulberry can grow up under the wide range of climate conditions. It had been found in warm temperature, subtropical and tropical regions. This plant is a fast pioneer tree and it grows up to 4-9 meters within one year. It grows fast under moist sandy loam soil in lowland areas, which close to stream and river valleys. However, it can also be grown in upland areas as well for instance, upland rice field, hillside fallow, but the growth rates on the upland fields are lower.

The inner bark of paper mulberry has been utilized to produce paper and textile fabric for clothing for centuries, particularly in Japan, China, Indo-China, Thailand, Myanmar, the Philippines, Java and Madura. Paper mulberry textile fabric, which is called Tapa cloth, has used to make several clothing items for instance, head-clothing, sarongs, bed clothing, and bags. Moreover, leaves are considered as medicine for children and diaphoretic, fruits are for stomachic and tonic, bark is laxative for dysentery and haemorrhage and milk-sap is external use for against dog and snake bites and bee stings (NEEF et al, 2010).

Materials and methods

Effective Propagation of Paper Mulberry

There are some propagation methods of plants, e.g. seeding, cutting, and root division. The root division is the most general method of propagation of Paper Mulberry. However, it seems that a lot of efforts and expenses must be needed to propagate by this method because post mine area in open cut mine is so vast. Thus, the seeding which enables to propagate liberally at one time was selected as object of investigation and then discussed effective promoting germination method of the seeds of Paper Mulberry.

Seeds are often disturbed their germination because of physiological quiescence and hard seededness. Thus, it is needed to conduct adequate promoting germination method in order to accelerate and uniform the germination rate. In this paper, three types of treatments, hot water treatment, scratch treatment and acid treatment, were conducted and discussed as the effective germination of the seeds of Paper Mulberry. The seeds were sampled in nursery at the institute of tropical agriculture in Kyushu University in July, 2012.

A hundred of seeds are used for each treatment in this test. The seeds were immersed into 500 ppm of gibberellin solution overnight after each treatment and finally they were placed in dark place at 30°C in order to promote breaking of dormancy (Hamanaka et al, 2013). Budbreak number was counted periodically for four weeks and then total germination rate was calculated.

Applicability of Paper Mulberry in Post Mine Area

Field growth test was conducted from November 14,

2012 in post mine area in KPC mine which is the biggest open cut coal mine in Indonesia in order to examine the applicability of Paper Mulberry in post mine area of Indonesian open cut mine by using the seedlings of Paper Mulberry which were germinated by the seeding.

In this mine, the management of seedlings which were planted in post mine area was conducted at Nursery for efficient revegetaion process. In this Nursery, mixed soil which consists of topsoil, compost, manure, and lime was used as a plant base of the seedlings, and watering was conducted regularly. Under the present situation, the seedlings are transplanted to post mine area after growth for six months. However, it seems that the earlier transplanting to post mine area becomes possible in case of the plants which extend their underground roots and come to have tenacious vitality like Paper Mulberry.

Therefore, in order to examine the adequate period of transplanting of the seedlings from nursery to post mine area, the seedlings of which growth terms after germination was set for 1, 2, 3, and 6 months respectively were transplanted to the field. The height of the seedlings was measured once every two weeks. Fourteen of the seedlings were planted per a section (5m×10m). Moreover, fertilizer (NPK 16-16-16) which was used in KPC mine was applied with 300kg/ha when the seedlings were transplanted and once every three months after transplanting.

Laboratory Vegetation Test

Soil is one of important parameter when growth of plant is discussed. In order to find proper soil properties for Paper Mulberry, laboratory vegetation test about this species was implemented under the various soil conditions. The seedlings of Paper Mulberry were planted to pots one by one filled soil mixed with sand and clay artificially. This vegetation test continued for 2 months, and measured height and diameter every a week. The dry weight of aerial part and root were measured at the end of this test. All pots were supplied with 500mL water every 3~ 4 days, while liquid fertilizer HYPONeX○,R (N-P-K = 6-10-5) at the concentrate of 2 ml per liter of water applied weekly. The experiment was carried out in constant temperature and humidity room, which was controlled temperature and humidity at 30°C and 70%, respectively.

Results and discussion

Effective Propagation of Paper Mulberry

The results of germination test show that these treatments have a certain effect to improve germination rate without hot water treatment at 100°C and acid treatment for 60 seconds (Figure 3). In these two kinds of treatments, it seems that germination rate was decreased because inside of the seeds were affected and embryos became unable to work. In this test, the treatment that immerses the seeds of Paper Mulberry into hot water at 80°C for 10 seconds showed the highest germination rate at least 80% and it is about four times higher compared with no treatment seeds. Furthermore, as hot water treatment is simple and easy method, it can be considered that the effective propagation of Paper Mulberry is achieved by applying this promoting germination method.

Applicability of Paper Mulberry in Post Mine Area

Survival rate of Paper Mulberry shows significantly higher in this test though just three seedlings were died. Thus, it is indicated that the seedlings of Paper Mulberry can grow up in post mine area in open cut mine in Indonesia. Moreover, it is indicated that earlier transplanting to the field is possible in case of planting Paper Mulberry. However, the results of field vegetation test show that the plant growth of earlier transplanting seedlings is lower than that of 6 month curing period in nursery (Figure 4). This is due to inhibited by cover crop, which spread to post mine area for minimizing erosion and sediment generation. This result suggests that the plant growth is easy to be affected by cover crop when the curing period in nursery is not enough. From these results, it is revealed that Paper Mulberry can grow up in the post mine area and earlier transplanting of the seedlings can simplify vegetation management at nurs-

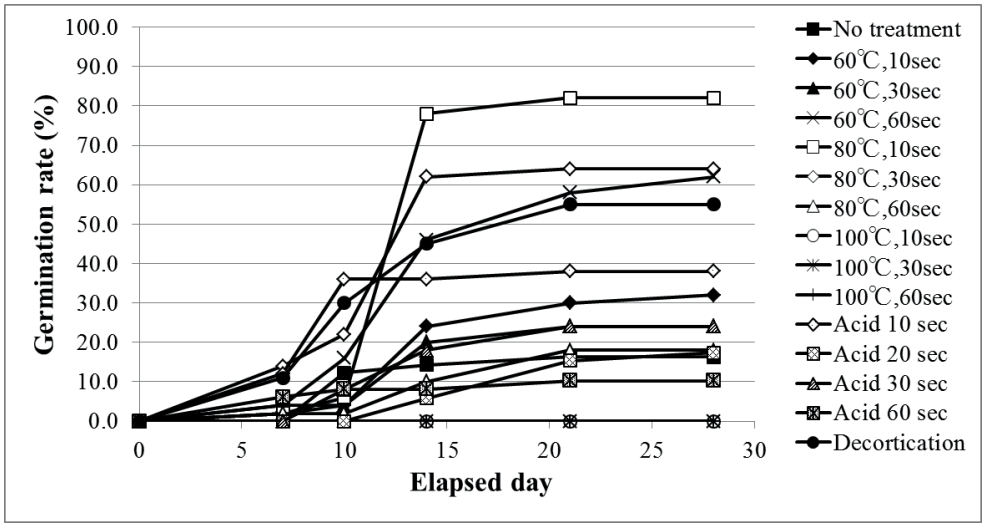

Fig. 3 The results of germination test

Rys. 3 Wyniki prób kiełkowania

Tab. 1 Soil compositions and basic soil characteristics

Tab. 1 Zawartość i podstawowa charakterystyka gleby

Soil Sample	Sand (%)	Clay (%)	Liquid limit W_L (%)	Plastic limit W_P (%)	Plasticity index I_P	Coefficient of permeability (cm/sec)	CEC (cmol/kg)
Soil1	100	0	28.3	Np	-	8.770×10^{-4}	10.55
Soil2	85	15	33.7	14.8	18.9	3.491×10^{-4}	11.12
Soil3	75	25	40.7	17.6	23.1	2.431×10^{-4}	13.07
Soil4	65	35	45.2	18.2	27.0	1.443×10^{-4}	15.42
Soil5	55	45	52.3	20.1	32.3	8.250×10^{-5}	16.48
Soil6	40	60	57.1	22.5	34.6	3.450×10^{-6}	20.70
Soil7	0	100	67.2	23.6	43.6	$1.000\times10^{-7}>$	26.39

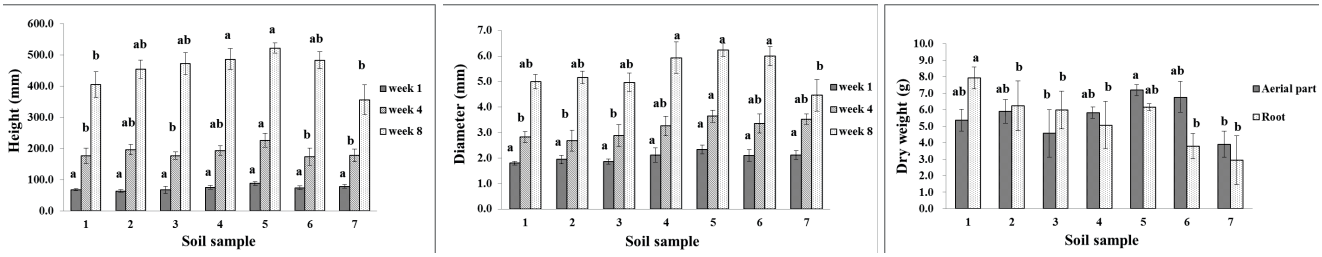

Fig. 5 The results of laboratory vegetation test: (a) height of seedlings, (b) diameter of seedlings. (c) dry weight of aerial part and root

Rys. 5 Wyniki laboratoryjnego testu wegetacji: (a) wzrost siewek, (b) średnica sadzonek, (c) sucha waga części nadziemnej i korzeni

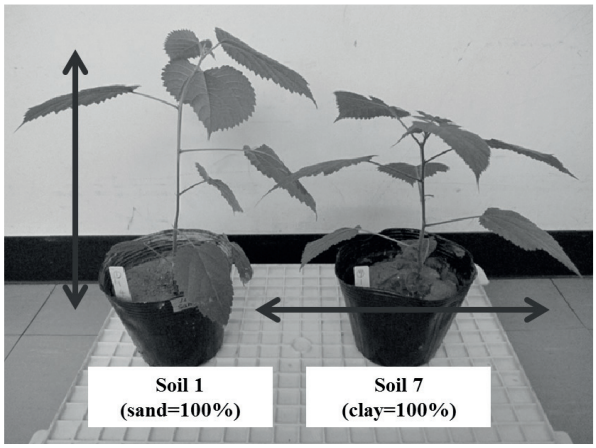

Fig. 6 Difference of the plant growth shape in soil 1 and soil 7

Rys. 6 Różnice wzrostu rośliny w glebie 1 i glebie 7

ery. However, the management of cover crop in-situ or the selection of the type of species to minimize the impact to plant growth has to be considered when the seedlings transplant to the field earlier.

Laboratory Vegetation Test

Table 1 shows the soil compositions and the basic soil characteristics used in laboratory vegetation test. It can be understood that permeability decreases and CEC represented fertilizer holding capacity increases with increasing clay content. Therefore, it can be said that the various type of soil can be expressed by mixing with sand and clay.

Figure 5 shows the results of laboratory vegetation test; height of seedlings, diameter of seedlings and dry weight of aerial part and root. The different alphabets in these figures show a significant difference obtained by Tukey-kramer method (Nagata and Yoshida, 2001). This method is one of the statistical tests and used to show the clear differences among the each result.

According to the results, the soil 4 and soil 5 gave higher height value than other soil compositions whereas the height and diameter of seedling in soil 1 and soil 7 was lower than them at the end of test.

The diameter of seedlings is higher in soil 4, 5, and 6, while that is lower in soil 7. Moreover, dry weight of aerial part shows the highest value in soil 5 and lowers in soil 3

and 7, and that of root is the highest in soil 1 and lower in soil 6 and 7. From these results, it can be considered that growth of seedlings is affected by basic soil characteristics as plant base such as permeability and water and/or fertilizer holding capacity.

Moreover, the figure of plant growth in soil 1 and soil 7 can be found clear differences as shown Figure 6. The plant on sandy soil grows up to axial direction and the plant on clay soil grows up to horizontal direction. It can be said that growth form of the plant is also affected by the difference of soil characteristics. The growth of plant can be promoted by not only growing up to axial direction but also horizontal direction for increasing photosynthesis. It can be considered that growth form of Paper Mulberry can be expected under the appropriate soil condition.

From a comprehensive point of view, soil 5 (sand:clay = 55:45) can be expected the proper soil composition for growth of Paper Mulberry and the seedlings are grown up in optimum growth shape in soil 5 because the height and diameter of seedlings and dry weight of aerial part shows the highest value.

In addition, the recovery rate of fibre resources from Paper Mulberry can be also improved by promoting the growth rate. Therefore, it is important for growth of Paper Mulberry to backfill the soil with a ratio of sand to clay of 1:1, furthermore, comprehensive consideration have to be needed with available topsoil in-situ and organic fertilizer.

Conclusion

Paper Mulberry is one of efficient species for not only earlier revegetation but also utilization for product uses in post mine area. The results from germination test indicate that the promoting germination method of the seeds of Paper Mulberry enables efficient propagation. From field vegetation test, it is possible for this plant to grow up in post mine area in Indonesian open cut mine even in case of short management period in nursery though the management of cover crop have to be taken into consideration. Furthermore, the plant growth can be improved by backfilling the soil which has proper soil characteristics as plant base.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 24404025. The first author is grateful for financial assistance provided by the Advanced Graduate Program in Global Strategy for Green Asia, Kyushu University. We also wish to extend their grateful thanks to PT Kaltim Prima Coal in Indonesia for the acceptance of visiting mine sites and cooperation in providing the samples and field used in this study.

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Rekultywacja odkrywkowych kopalni węgla
z użyciem morwy papierowej (Broussonetia papyrifera) w Indonezji

Większość węgla w Indonezji produkowana jest w kopalniach odkrywkowych. W poprzednich latach, producenci węgla indonezyjskiego zwiększyli produkcję węgla i rozwijają nowe kopalnie węgla aby przystosować się do dużego zapotrzebowania na węgiel na całym świecie. Jednakże działalność wydobywcza w kopalniach odkrywkowych ma ogromny wpływ na otaczające środowisko. Z tego powodu odpowiedni program rehabilitacji musi zostać rozważony gdy projektuje się plan kopalni. Podstawowy koncept rehabilitacji kopalni odkrywkowych obejmuje stworzenie stabilnej i samowystarczalnej powierzchni terenu miejscu po kopalni, włączając w to tworzenie warunków odpowiednich dla ustanowienia i ciągłego rozwoju gęstego pokrycia wegetacyjnego. Dodatkowo, utylizacja tych terenów w inny sposób, mający potencjał ekonomiczny była rozważana w ostatnim czasie. Można zauważyć, że morwa papierowa jest jednym z gatunków, którego uprawianie w terenie rehabilitacji może być wydajne. Gatunek ten jest drzewem szybko rosnącym i może rosnąć w ciepłej temperaturze w terenach subtropikalnych i tropikalnych i w różnych warunkach glebowych. Istnieje wiele możliwości wykorzystania morwy papierowej, między innymi wytwarzanie papieru, elementów ubioru oraz w medycynie. W pracy tej poddano badaniom zastosowanie morwy papierowej, które posiada dwie cechy – drzewo jest szybko rosnące i może być produktywnie użyte w naruszonym działalnością obszarze, użyto w tym celu różnych testów laboratoryjnych i terenowych. Udowodniono, że 1) obróbka w gorącej wodzie w 80°C przez 10s jest najbardziej efektywnym zabiegiem polepszającym szybkość kiełkowania (powyżej 80%), 2) morwa papierowa może rosnąć w terenach rehabilitowanych w indonezyjskich kopalniach odkrywkowych, a prowadzenie rozsad w szkółkach może zostać uproszczone przez przesadzanie do terenu na wczesnym etapie w celi zmniejszenia konkurencji z roślinami okrywowymi musi zostać wzięte pod uwagę, 3) odpowiednie zarządzanie teksturą gleby w terenie może promować tempo wzrostu tego gatunku pod względem źródła włókien.

Słowa kluczowe: przeróbka gorącej wody, kopalnia odkrywkowa, papier z morwy, rekultywacja, gleba