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Research Article

Hydroseeding application using pioneer local plant seeds for coal postmining soil in Tanah Laut Regency, South Kalimantan

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Abstract: The research aimed to determine pioneer local plant seeds germination and growth on coal postmining soil, and to determine optimal mulch for producing great productivity. The research was conducted in two applications in a coal post mining area, Tanah Laut, South Kalimantan. The used seeds were 5 species of legumes, 3 species of grasses, and 3 species of sedges. Hydroseeding was applied by mixing seeds in mulch and spreading it on soil surface of 400 cm^2 plots (1st application) and 10,000 cm^2 plots (2nd application). There were five treatments in the 1st application and repeated four times, while in the 2nd, there were six treatments with three times repetitions. Germination rate, seedling density, plant coverage, height/length, and leaf length were observed every three days (1st application). On 60 days after sowing, root length and plant biomass (the 1st), and plant coverage, height and productivity (the 2nd) were measured. The results showed that hydroseeding mulches could be media for pioneer local plant seeds germination and seedling growth especially for Leguminosae. While the buffalo dung could be hydroseeding mulch for Poaceae growth. Although root/shoot ratio of Cyperaceae was higher than other families, Leguminosae root developed longer as shoot growth and well adapted on postmining soil. The hydroseeding mulch composed by 720 seeds per plot and applied 4 cm in depth was optimal based on seed germination percentage. Whereas mulch with 0.2 cm depth in 2nd application showed a higher effectivity for plant growth and productivity.

***Keyword**: hydroseeding, local plants, mining soil, revegetation*

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Introduction

Mining has become the biggest contributor to the economic development of Indonesia for about last 30 years (Manaf, 2009). The main area of coal deposits in Indonesia are Northern Sumatra (54%), Eastern Kalimantan (28%), Southern Kalimantan (10%), Riau (2%), and Central Kalimantan (1.4%) (Ministry of Energy and Mineral Resources, 2008). Based on data of the General Directorate of Fiscal Balance at the Ministry of Finance of the Republic of Indonesia (2012), the mining sector in Southern Kalimantan contributes revenue of 24.42% of the total Gross Domestic Product (GDP) in 2011, which reached IDR 68,234 billion. Coal mining produces 141,809,435 million tonnes from eight producer districts, namely Tanah Laut, Kota Baru, Banjar, Tapin, Hulu Sungai Selatan, Tabalong, Tanah Bumbu, and Balangan.

Generally, the technique of coal mining in Kalimantan uses open pit mining techniques with back filling methods (Darmawan and Irawan, 2009; Subandrio et al., 2009). The negative impact of mining is the loss of soil cover because topsoil and subsoil are reversed and moved, while the main material of rocks appears on surface. The oxidation process of sulfide minerals such as pyrite will release sulfuric acids that have negative impacts for decreasing drastically soil pH and affecting the balance of nutrients in the soil (Rochani and Damayanti, 1997). Topsoil displacement also causes loss of soil organic matter, while nutrients will be leached when rain falls. Nutrient and organic matter poor soil has low capacity for plant growth, fertilizer application and water holding (Djajakirana, 2001).

Post-mining land reclamation and revegetation are held to overcome negative impacts of mining activities because of the open pit mining techniques. It aims to improve the disturbed land use after mining operations, as well as to accelerate plant coverage and its ecological service as intended (Decree of the Minister of Energy and Mineral Resources No. 1211.K/008/M.PE/1995; Decree of the Minister of Forestry and Plantation No. 146/Kpts-II/1999). Among revegetation methods, hydroseeding becomes promising. Hydroseeding is a planting process using a mixture of seeds and mulch that mixed together and sprayed on the land that has been prepared. Unstable soil surface due to the displacement of vegetation, native soil, and debris on coal mining was successfully revegetated with hydroseeding using grasses, legumes and fertilizer nutrients (Zipper et al., 2012).

Revegetation as a part of diversity restoration program increases the accumulation of carbon and structures by involving direct carbon input through mulching and transplanting. These efforts are particularly applied by using fast growing ground cover plants that can stabilize the soil surface (Walker and del Moral, 2008). However the local plants as seed sources in post mining land revegetation is greatly selected due to its adaptation to local biotic and abiotic factors (Oliveira et al., 2013). Meanwhile, in Tanah Laut Regency, a herd of buffalo that visits and grazes in post-mining land left dung that is essentially an example of a natural hydroseeding. In a few weeks, various grasses grow naturally from the decomposed dung. Therefore, it is interesting to use the buffalo dung hydroseeding model and imitate it for an artificial hydroseeding using pioneer local plant seeds using different mulches composition in coal post-mining soil. The aims of this study were to evaluate the hydroseeding applications using local plants seeds and some mulches composition, determining its germination and growth in coal post-mining soil, and selecting the optimal mulch likes buffalo dung performance.

Materials and Methods

A field research was conducted in two steps of application. The first one was held from January to April 2015 in the rainy season and the second step was held from February to May 2017, in PT Amanah Anugerah Adi Mulia Site Kintap. It is located in Riam Adungan Village, Kintap District, Tanah Laut Regency, South Kalimantan, with four points of coordinate boundaries of Production Operation Mining Permits (IUP.OP) and approximately 33 km from Southern of Trans South Kalimantan Road (Figure 1). The mining area is around 599.78 ha, and bordered on the North by IUP of PT WTB, on the West by IUP of KUD TJM, on the South by IUP of PT Ananta, and on the East by the areas of limited production forest. The nearest villages are Riam Adungan and Salaman within ± 6-10 km. The annual rainfall is 1,771.5 mm.

The collected seeds that were dried consisted of five species of Leguminosae (*Cajanus cajan* (L.) Millsp., *Crotalaria pallida* Aiton., *Desmodium triflorum* (L.) DC., *Indigofera spicata* Auct., *Sesbania grandiflora* (L.) Pers.), three species of Poaceae (*Eleusine indica* (L.) Gaertn., *Sporobolus indicus* (L.) R. Br., *Paspalum conjugatum* PJ Bergius), and three species of Cyperaceae (*Cyperus brevifolius* (Rottb.) Endl. ex Hassk., *Cyperus odoratus* L., *Kyllingia monocephala* Rottb.). These pioneers were found growing wild in the post coal-mining area of PT Amanah. The seeds were soaked with water for 24 hours. The sinking seeds were then treated with Gibberellic Acid (GA3) for 1 hour and mixed with mulch. Number of seeds used for 360 seeds density was composed by 60 seeds of Leguminosae, 150 seeds of Cyperaceae, and 150 seeds of Poaceae. Number of seeds used for 720 seeds density was consisted by 120 seeds of Leguminosae, 300 seeds of Cyperaceae, and 300 seeds of Poaceae.

According to the results of preliminary studies, mulch of the 1st application was made from a mixture of wood fibers, water, local microorganisms (mol), adhesive, compost, charcoal, and ash. Mulch was then added with seeds of all plant species proportionally with two different densities, 360 seeds (B_1) or 720 seeds (B_2) per plot. After mixing, the mulch was spread over 20 cm x 20 cm on the post-mining soil plots with two levels of depth, which were 4 cm (M_1) and 6 cm (M_2), and a control (fresh buffalo dung with 2 cm depth). All treatments were repeated four times, while watering and observation were held every three days for 2 months. For the 2nd application, mulch (M_3) was composed by tackifier agent, water, compost, rice husk, sawdust, and urea. Mulch was mixed with plant seeds proportionally and stirred up until forming a slurry mixture, and then it was spread over 100 cm x 100 cm plots. It was repeated three times.

Figure 1. Hydroseeding application site in coal postmining soil at PT Amanah, Tanah Laut Regency, South Kalimantan

In the 1st application we observed seeds germination time in every planting medium. The number of germinated seeds was divided by the sown seeds number to determine the seed germination rate. The growth variables of seedling included plant height, leaf length, root length, biomass (shoot and root), and productivity. Vegetation analysis was conducted to determine density and coverage of Leguminosae, Cyperaceae, and Poaceae. On 60 days after sowing, all seedlings were harvested, we determined root length, biomass and productivity. While in 2nd application we observed plant coverage, height, and productivity.

Germination and seed growth data such as height, number of leaves, root length, density and coverage, biomass (shoot and root), and productivity were compiled using Microsoft Excel program. Furthermore, data of density, coverage, root/shoot ratio, root nodules, and productivity, were univariately statistical analyzed. While data of germination and growth variations on some planting media were analyzed multivariately by biplot and cluster analysis using PAST software (Hammer et al., 2001).

Results and Discussion

Seeds germination of some pioneer local plants on mulches

The prepared hydroseeding mulches could be served as seeds germination media especially Leguminosae seeds. While the fresh buffalo dung mulch as control, could be Poaceae seed germination medium (Figure 2). Mulch depth and seed density affected seedling number. A thinner mulch (M_1) produced more seedling number than M_2. Thick mulch and sun were observed as limiting factors of grass seed germination. In addition, higher density seeds mulches (B_2) also produced more seedling number than B_1 mulches (Table 1). Nevertheless, the seedling number in this experiment was still very small, ranged 1-5%. However in the greenhouse experiment, the most Leguminosae seeds produced 40% seedling on 12 days after sowing (Baiti and Arisoesilaningsih, 2015). Some possible factors produced this low germination rate of Leguminosae seed in post-mining land were fungal attack, low viability of seeds, and seed predation by ants (Anshari, 2015). Fungal attack occurred if the medium was very acidic and moist. In addition, immature seeds germination stimulated the fungi growth (Utomo, 2006). According to Abella et al. (2009), some variables influencing seed germination success were selection of species, genetic stock, and rate of germination, given treatment, environmental conditions, germination time, and rainfall. To overcome this low seeds germination, increasing number and better selection of seeds could be conducted. Soaking seeds in hot water with certain temperature and duration is another method to raise seed germination rate, particularly for Leguminosae seeds (Kak et al., 2007; Naikawadi, 2016).

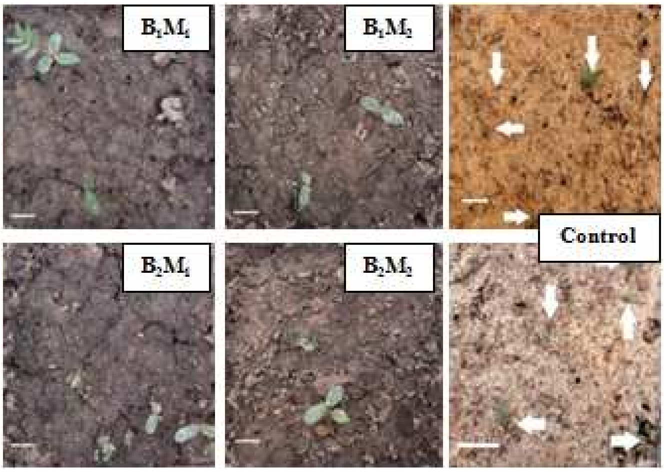


Figure 2. Seed germination of some pioneer local plants at 15 days after sowing on mulches
Note: B_1: 360 seeds density; B_2: 720 seeds density; M_1: 4 cm depth; M_2: 6 cm depth;
Control: Fresh buffalo dung with 2 cm depth. Scale represents 2 cm.

Table 1. Cumulative seedling number of three pioneer local plant families grown on mulches until 15 days after sowing

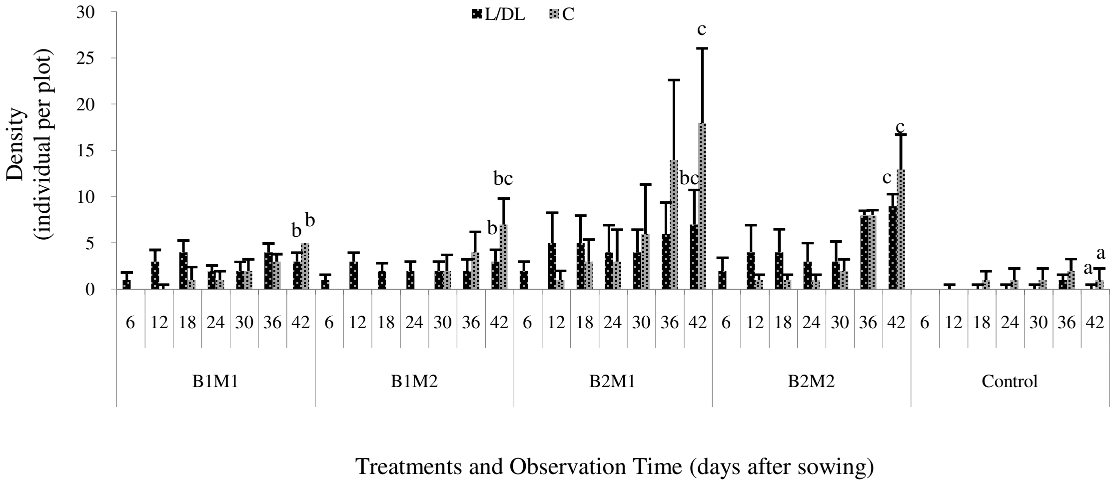
No	Families	Total Seedling (individual)				
		B_1M_1	B_1M_2	B_2M_1	B_2M_2	Control
1	Leguminosae/Broadleaf plant	3 (5)	2 (3)	6 (5)	6 (5)	1
2	Cyperaceae	3 (2)	4 (3)	12 (4)	6 (2)	2
3	Poaceae	3 (2)	2 (1)	12 (4)	4 (1)	99

Note: Numbers in parenthesis indicate relative seedling number (%), compared to the sown seeds; B_1: 360 seeds density; B_2: 720 seeds density; M_1: 4 cm depth; M_2: 6 cm depth; Control: Fresh buffalo dung with 2 cm depth.

Seedling growth of some local plant families on mulches

Density of Cyperaceae seedling until 42 days after sowing tended to increase irregularly in each observation. The highest density was recorded on B_2M_1 treatment and reached 18 individuals/400 cm^2, followed by B_2M_2 treatment reached 13 individuals/400 cm^2. Moreover in Leguminosae/broadleaf plants, seedling density until 42 days after sowing tended to fluctuate due to herbivore attack or seedling death. The highest seedling density was observed in B_2M_2 treatment and reached 9 individuals/400 cm^2, while in B_2M_1 treatment it reached 7 individuals/400 cm^2 (Figure 3A). Differently with two previous families, Poaceae seedling density until 42 days after sowing tended to increase, with the highest density in control plots that reached 355 individuals/400 cm^2. While in all treatments, Poaceae density was very low compared to control, respectively 24 individuals/400 cm^2 and 10 individuals/400 cm^2 in B_2M_1 and B_2M_2, (Figure 3B). These results revealed that seedling density in the mulch with 720 seeds density (B_2) was significantly higher than seedling density in the mulch with 360 seeds density (B_1). Seed quality and dormancy, inhibitors presence, and predation might serve as limiting factors (Anshari, 2015). However, the mulch in control was more suitable for Poaceae growth medium. It is assumed that it closely related with buffalo's diet. Lancelotti and Madella (2012) showed that buffalo dung was composed by grass leaf/culm and grass inflorescence/seeds due to commonly the buffaloes graze in the pasture lands. Poaceae is the most important fodder for buffalo (Harun et al., 2017). From 53 species of Poaceae, there were 27 species of buffalo fodder in Central Punjab. Additionally, Zereen et al. (2013) stated that Poaceae played a significant fodder because almost all of 51 species of Poaceae in Central Punjab, were used as fodder for the animals, including buffalo.

Coverage of some local plant families increased until 60 days after sowing. The highest Leguminosae coverage was seen in B_2M_2 treatment and reached 36.25% (Figure 4A). While in Cyperaceae and Poaceae, the highest coverage found in M_3 treatment, respectively 13.84% and 37.74%. In the controls, Poaceae dominated with highest coverage and reached 78.75% (Figure 4B-C and Figure 5). This result was still less than those reported by Fan et al. (2013). They showed that Poaceae coverage on 60 days after application reached more than 90%. The control mulch could be similar as compost blanket as reported by Faucete et al. (2006). They revealed that blanket compost with 3.75 cm depth provided vegetation coverage 2.75 times greater in three months compared to hydroseeding treatment. This greater vegetation coverage on the compost treatment was likely due to their ability to maintain moisture. Then the lower coverage on hydroseeding was possibly caused by drained seeds during rainfall and or greater evaporation after hydroseeding treatment. Therefore erosion control could be provided by combining compost and a thicker hydroseeding application.



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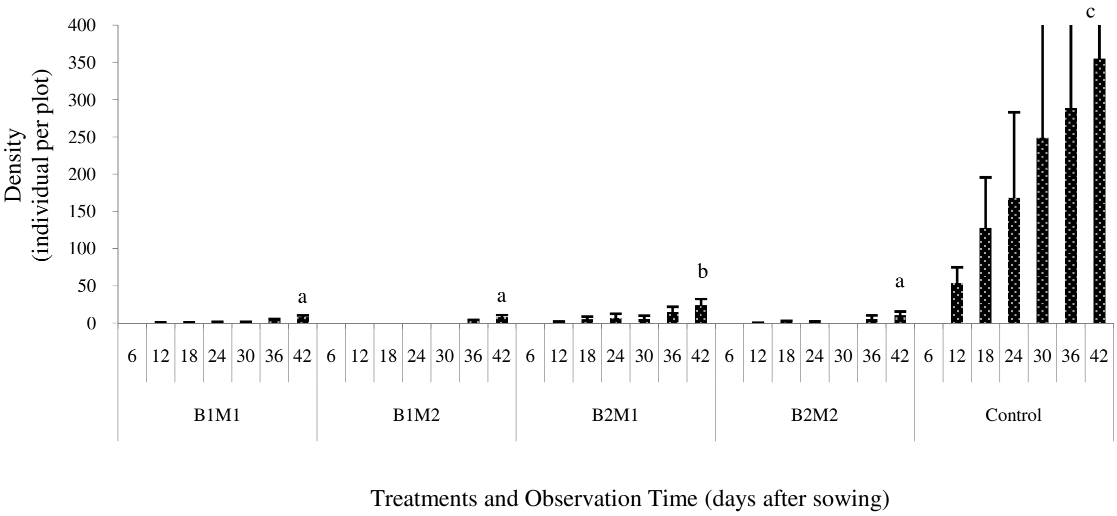

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Figure 3. Seedling density of pioneer local Cyperaceae, Leguminosae/broadleaf plant, and Poaceae until 42 days after sowing on mulches. Plot size is 400 cm^2.

Note: A: Cyperaceae and Leguminosae; B: Poaceae; C: Cyperaceae; L/DL: Leguminosae/broadleaf plant; P: Poaceae; B_1: 360 seeds density; B_2: 720 seeds density; M_1: 4 cm depth; M_2: 6 cm depth; Control: Fresh buffalo dung with 2 cm depth. Different letters in each family indicate significantly different based on Mann-Whitney test p= 0.05.

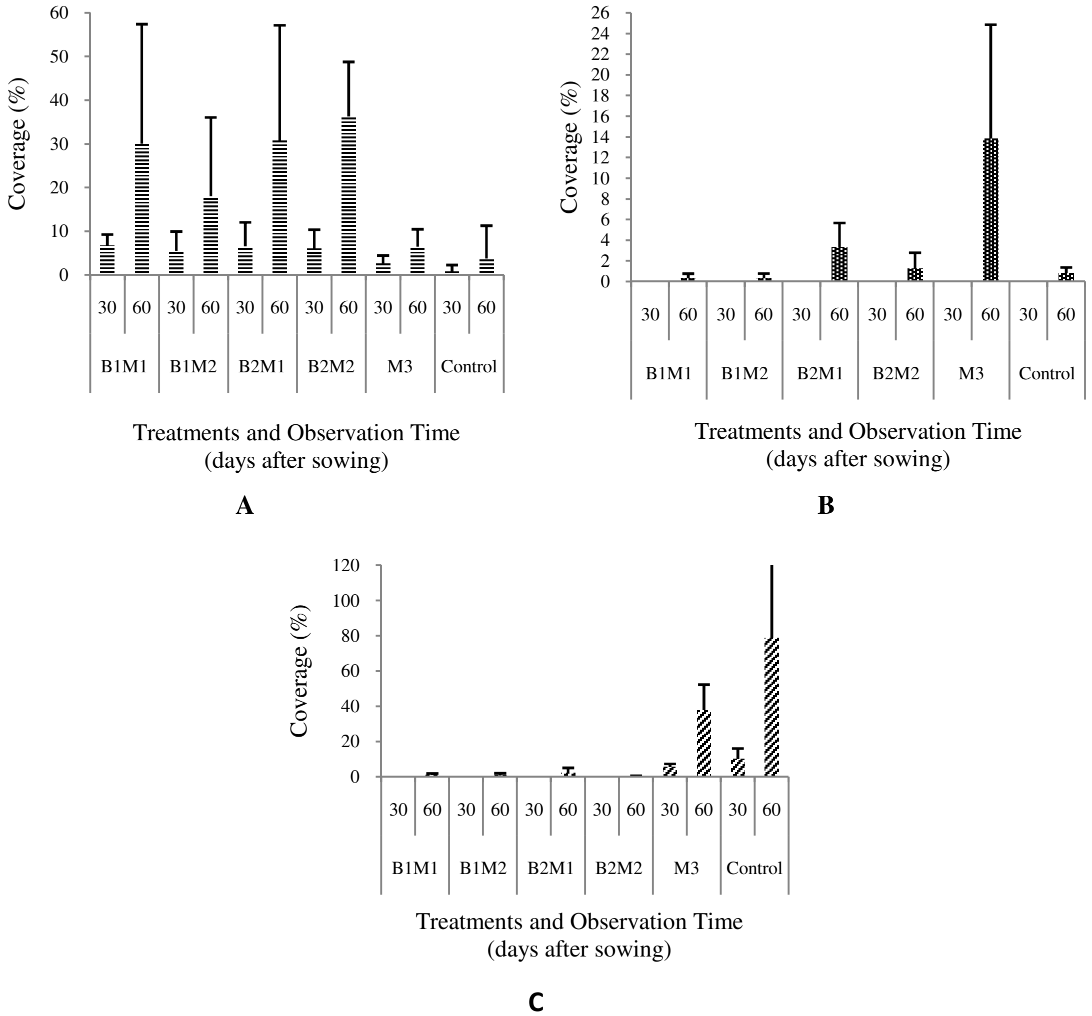


Figure 4. Coverage of pioneer local Leguminosae/broadleaf plant, Cyperaceae, and Poaceae until 60 days after sowing on mulches

Note: A: Leguminosae/Broadleaf plant; B: Cyperaceae; C: Poaceae; B_1: 360 seeds density; B_2: 720 seeds density; M_1: 4 cm depth; M_2: 6 cm depth; M_3: 0.2 cm depth; Control: Fresh buffalo dung with 2 cm depth.

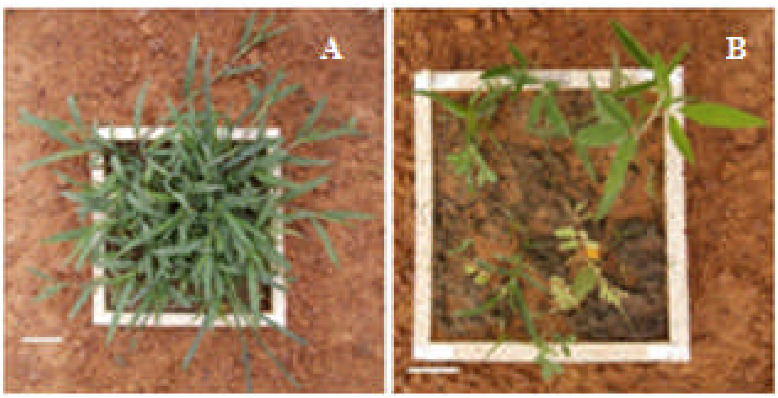


Figure 5. Coverage of some pioneer local plant families

Note: A: Control plot; B: Hydroseeding treatment plot. Scale represents 2 cm.

Among the five species of Leguminosae family, namely *C. cajan*, *C. pallida*, *D. triflorum*, *I. spicata*, and *S. grandiflora*, there were only three species grown and had root nodules until 60 days after sowing. They were *C. cajan*, *C. pallida*, and *S. grandiflora* (Figure 6). It was different from a green house experiment conducted by Baiti and Arisoesilaningsih (2015), which showed that growth of nodules on *C. pallida*, *D. triflorum*, and *I. spicata* after 37 days after sowing. The inside nodule was still yellow and not red, so that the nodule had not been functional. Number of functional root nodules could increase of soil nitrogen. Soil nitrogen fixation by Leguminosae increases the limited nitrogen level in post-mining soil for root growth (Singh et al., 2012). Post-mining soils generally have a low nitrogen content that limits vegetation establishment and sustainable productivity (Tripathi and Singh, 2008).

Legume cultivation on marginal soils would be a multiple functions, such as cultivation crop, forage provision, green manure, and reduced artificial fertilizers use (Bruning and Rozema, 2013). The average number of three species nodules varied in each treatment. Root nodules number of *C. cajan*, *C. pallida*, and *S. grandiflora* in mulch with 4 cm depth (M_1) tended to be more than mulch with 6 cm depth (M_2) (Figure 6). Among three pioneer local plant families harvested on 60 days after sowing, Cyperaceae showed the highest value of root/shoot ratio compared to Leguminosae/broadleaf plant and Poaceae grown on all treatments (Figure 7).

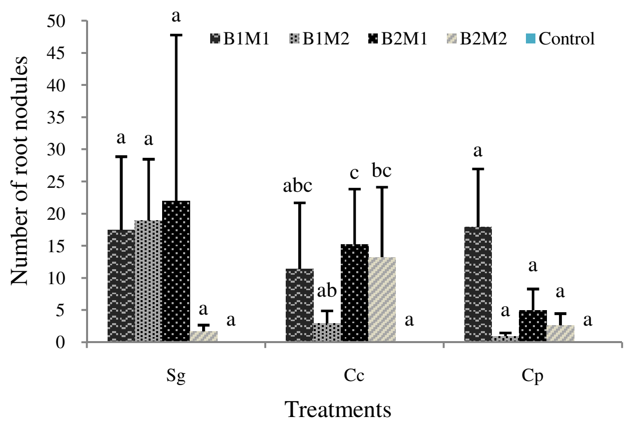


Figure 6. Number of pioneer local Leguminosae root nodules until 60 days after sowing on mulches

Note: Sg: *S. grandiflora*; Cc: *C. cajan*; Cp: *C. pallida;* B_1: 360 seeds density; B_2: 720 seeds density; M_1: 4 cm depth; M_2: 6 cm depth; Control: Fresh buffalo dung with 2 cm depth. Different letters in each species indicate significantly different based on Duncan test p=0.05.

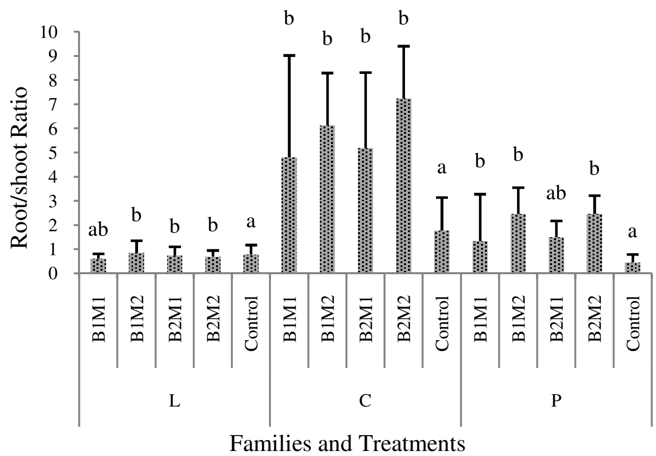


Figure 7. Root/shoot ratio value of three pioneer local plant families

Note: L: Leguminosae; C: Cyperaceae; P: Poaceae; B1: 360 seeds density; B2: 720 seeds density; M1: 4 cm depth; M2: 6 cm depth; Control: Fresh buffalo dung with 2 cm depth. Different letters in each family indicate significantly different based on Duncan test p=0.05.

Although root/shoot ratio of Cyperaceae was higher than other two families, but Leguminosae root system was longer and developed better in the post-mining soil comparing to the shoot growth. Leguminosae had root/shoot ratio value <1 in B_1M_1, B_2M_1, B_2M_2, and control. Poaceae root/shoot ratio value >1 was found in B_1M_1, B_1M_2, B_2M_1, and B_2M_2 (Figure 7). This accorded to experiment conducted by Baiti (2015), that Leguminosae had root/shoot ratio <1, and Rahma report (2015), which indicated that the root/shoot ratio >1 was found in Poaceae. Root/shoot ratio value >1 indicates that the plant root size is longer than the shoot. Some Poaceae showed a fast growth capacity, shallow rooting, and naturally able to creep well (Fan et al., 2013). Root/shoot ratio varied among species, growth rate, soil character, and available nutrients in the media. According to Tripathi et al. (2012), well developed root system had an important role in the rocks slope stabilization in coal mining areas. Root provided mechanical reinforcement to waste material through root proliferation. Species characteristic difference in growth and its interactions also determine succession rate in unfavorable environmental conditions (Walker and del Moral 2008).

Productivity of some pioneer local plant families on mulches

The highest total plant productivity was found in control plot and reached 97 g/m^2/month (Figure 8). Shoot productivity of all treatments was similar and greater value than the root one. Plant root and total productivity in hydroseeding plots were significantly lower than those of control plots. It revealed that the different mulches effected more significantly on the root part than on the shoot one.

Plant productivity was influenced by environmental factors, available nutrients in media, and density of growing seeds (Susilowati, 1999).Structural vegetation change in plant coverage and biomass production correlated with some soil changes such as accumulation of organic matter, nutrient content, porosity, and total nitrogen (Alday et al., 2012).

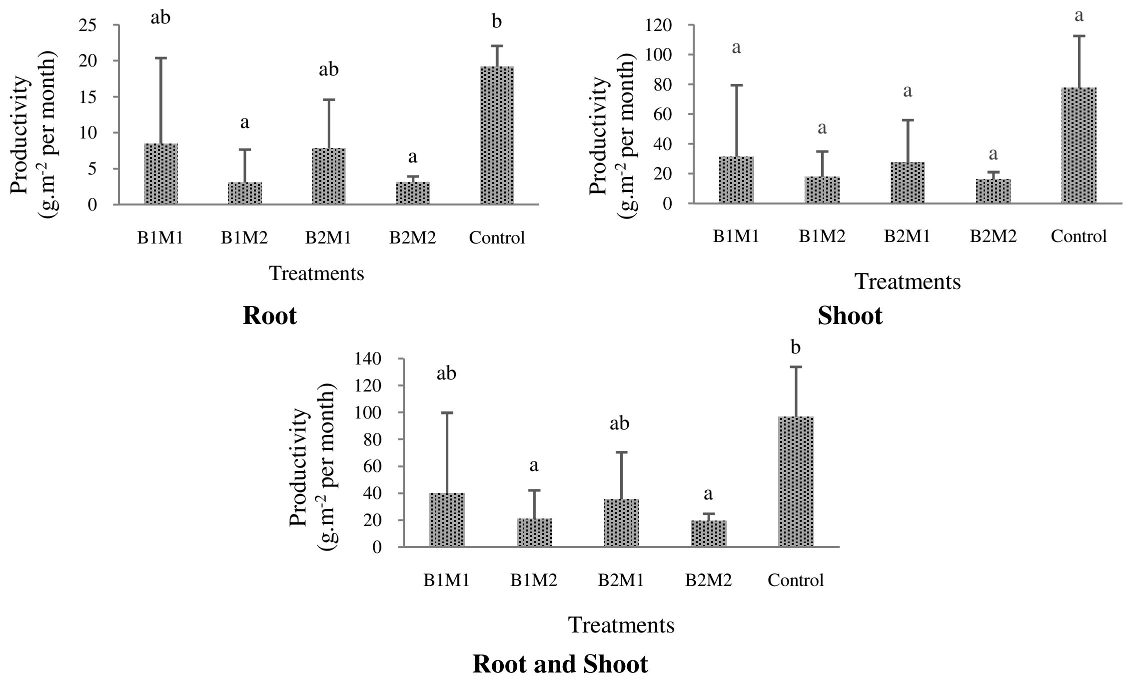


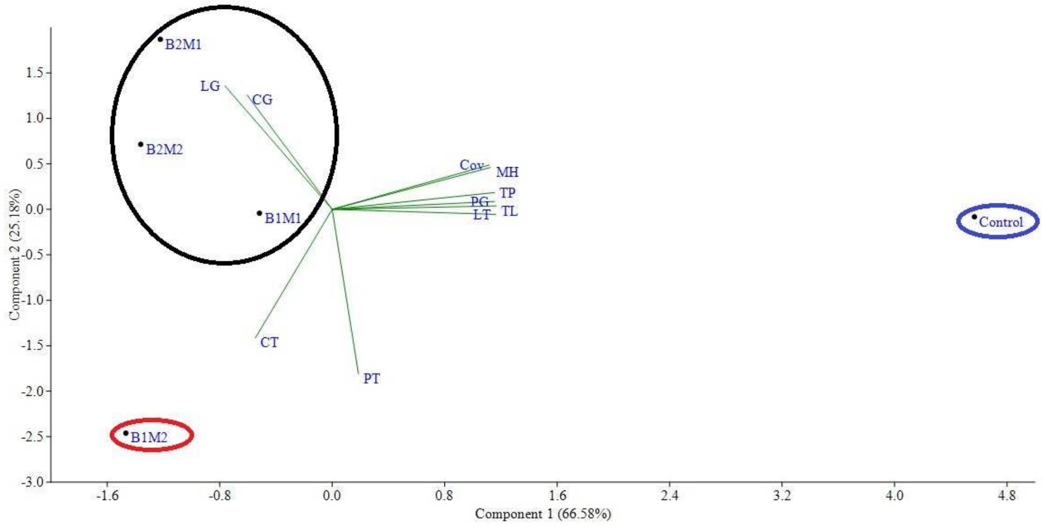
Figure 8. Plants productivity on mulches

Note: B_1: 360 seeds density; B_2: 720 seeds density; M_1: 4 cm depth; M_2: 6 cm depth; Control: Fresh buffalo dung with 2 cm depth. Different letters indicate significantly different based on Mann-Whitney test p= 0.05.

Multivariate profile of hydroseeding success

Based on multivariate analysis using biplot and clustering, it was shown that in the 1st application the artificial and natural hydroseeding had a respective success and advantage (Figure 9A). There were three profiles based on germination characteristics, growth, and plants families (TL), high Poaceae germination (PG), total productivity (TP), coverage (Cov), and maximum height

(MH). The second profile, was B_1M_1, B_2M_1, and B_2M_2, that characterized by high Leguminosae (LG) and Cyperaceae germination (CG). While the B_1M_2 treatment was the third productivity. The first profile was control as the best mulch and showed by a long Leguminosae germination time (LT), leaves number of three profile and was characterized by a long Cyperaceae (CT) and Poaceae germination time (PT). Comparing to the 1st application, M_3 treatment showed a higher profile of shoot productivity (SP) and maximum height (MH) rather than the previous results treatments or control. In addition, its coverage (Cov) was similar to the profile of control and even greater than other treatments. It showed an important progress of hydroseeding medium for seedling growth (Figure 9B).



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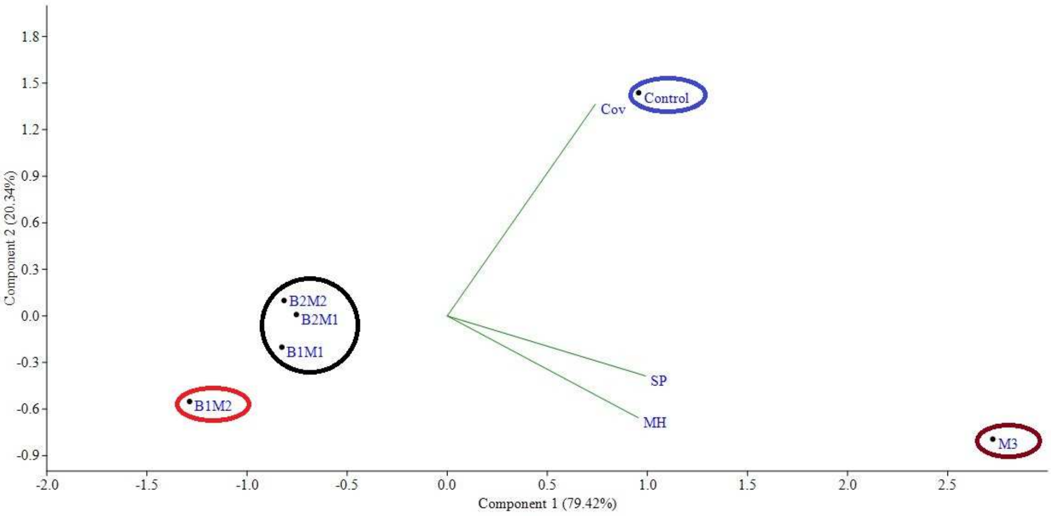

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Figure 9. Interaction among seedling density, growth, and plant productivity of treatment mulches and control based on biplot analysis.

Note: A: 1st application; B: 2nd application; B_1: 360 seeds density; B_2: 720 seeds density; M_1: 4 cm depth; M_2: 6 cm depth; M_3: 0.2 cm depth; Control: Fresh buffalo dung with 2 cm depth; LG: Leguminosae germination; LT: Leguminosae germination time; CG: Cyperaceae germination; CT: Cyperaceae germination time; PG: Poaceae germination; PT: Poaceae germination time; Cov: coverage; TL: Leaves number of three plant families; MH: Maximum height; TP: Total productivity; SP: Shoot productivity.

In accordance with a study conducted by Samir et al. (2016), organic manure content in growing medium had significant effect on seed germination and seedling growth characteristics. A quite similar result reported by Ngo et al. (2011) indicated that the addition of buffalo manure content improved the organic matter quality of disturbed tropical soils, and this improvement positively affected plant growth. A comparison among soil, mixed media I (100% cow dung), and mixed media II (70% cow dung + 30% food industry sludge), performed by Yadav and Garg (2015), showed higher value of several physico-chemical characteristics, such as pH, electric conductivity, total organic carbon, total Kjeldhal nitrogen, total potassium, total phosphorus, and carbon nitrogen ratio, in both of mixed media rather than the soil. Therefore, the artificial hydroseeding using local seed M_3 was more optimal but still need to be improved by increasing seed viability and germination rate, by selecting seeds from more diverse fast growing species of three families, as well as by controlling mulch thickness. For better seed germination and plant growth, we focus to the seed quality and appropriate mulch composition. Besides, revegetation success should be monitored more than 3 months for ensuring higher plant coverage and biomass accumulation.

Conclusion

Based on the findings, it was concluded that the hydroseeding mulch could be served as a medium for pioneer local plant seeds germination and growth, especially for Leguminosae and comparable to buffalo dung. Percentage of Leguminosae seeds germination was higher than Cyperaceae and Poaceae seeds. Meanwhile, the growth of each family was specific depended on its respective habitus. Although root/shoot ratio of Cyperaceae was higher than other two families, but Leguminosae root was longer following to shoot growth. Hydroseeding plant productivity of 1^{st} application was lower than control plots. In contrast, plant productivity of 2^{nd} application was higher. Mulch with 720 seeds density (B_2) and 4 cm depth (M_1) was more optimal used in hydroseeding applications based on seed germination percentage of three pioneer local plant families, while mulch with 0.2 cm depth (M_3) was more effective for growth and productivity of plant.

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