JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
ISSN: 2339-076X (p); 2502-2458 (e), Volume 3, Number 4 (July 2016): 609-615
DOI:10.15243/jdmlm.2016.034.609

Research Article

Germination of seeds of some local pioneer plant species in different hydroseeding mulches for revegetation of post-coal mining soil

D. Azalia[*], C. Retnaningdyah, E. Arisoesilaningsih

Biology Master Programme, Faculty of Mathematics and Natural Sciences, Brawijaya University, Jl. Veteran no 1., Malang 65145, Indonesia

[*]corresponding author: moliydadinda@yahoo.co.id

Abstract: The purpose of this study was to determine the hydroseeding mulch optimum compositions for germination and productivity of a few species of local plants pioneer in the post-mining land of coal from South Kalimantan. The method used in this research was by hydroseeding technique. The species observed were *Crotalaria pallida, Cajanus cajan, Kyllinga monocephala, Paspalum conjugatum, Digitaria sanguinalis* and *Eleusine indica*. Seven variations of mulch were added to the post-mining soil. Planting seeds carried out were monoculture and polyculture. Each composition of mulch was replicated three times resulting in 147 pots. Seed germination was observed for 15 days. The results showed that all species were able to germinate and and grow well in the mulch that was added to the post-mining soil, except *Kyllinga monocephala* on mulch two, four and five and *Digitaria sanguinalis* on mulch four. The best mulch for plant growth was characterized by pH of 6.8-7.0, 47-59% organic matter, and energy ranging from 2,337.68 to 3,792.68 Kcal/kg. The highest percentage of germination was observed for *Cajanus cajan* (56.7%) and *Crotalaria pallida* (39.4%) on mulch two with germination time of eight and three days after planting. The lowest germination percentage was shown by *Kyllinga monocephala* at all mulch treatments (up to 30 days after planting). The optimum composition of mulch that could be recommended to accelerate the revegetation was mulch two (pH 7.06 and 59% organic matter), especially for *Leguminosae,* and mulch seven (pH 6.8 and 47% organic matter), especially for *Poaceae* and polyculture.

Keywords: *coal, hydroseeding, modeling, mining, revegetation.*

Introduction

Indonesia's mining sector contributes to deforestation by 10% and reached two million hectares annually (Sitorus et al., 2008). South Kalimantan is widely used as a mining location. Several materials are potential mines in the area, including coal mines. Total coal resources in Indonesia in 2011 reached 105 billion tons and approximately 75% of total coal production is exported to several countries such as Japan, Taiwan, South Korea and Europe (ESDM. 2011). High coal demand leads to the bigger opening of the coal mining areas. Coal mining in Indonesia is mostly done with the system open pit causing environmental damages such as disruption of hydrological function, reduction in species diversity, soil compaction, low soil pH, heavy metal pollution, and carbon sequestration (Patiung et al., 2011). Environmental conservation such as land reclamation after mining is thus needed to avoid greater environmental damage. The basic of land reclamation is modification of the existing system into the long–term sustainable system (Aronson and van Andel, 2006). The main component for long-term sustainability is the establishment of cover crops.

Some constraints in reclamation mostly occur due to an error selecting plants for revegetation and reclamation caused by lack of monitoring progress. Wood plants that are commonly chosen for revegetation are “acacia” and “sengon”, but these timber plants are not cover crops. Other obstacles in the natural succession of reclamation are slow plant growth because of low seed quality, and high cost The re-establishment of cover crops in an area having a large damage of post-mining land is complicated by a number of reasons such as lack of seed and limitation of seed dispersal. Hydroseeding technique can be used in reclamation of a wide area. This technique is widely applied on embankments, slopes and it is also used in the recovery of post-mining land (Catania et al., 2012). The main factors affecting hydroseeding in certain areas are mostly technical, such as the components used and the level of application (Ruiz et al., 2007).

It has been reported that the use of local plants such as grass, legumes and puzzles can accelerate revegetation. Baiti and Arisoesilaningsih (2015) reported that *D. triflorum, I. spicata, C. pallida and S. grandiflora* were able to germinate and grow in post-mining land, while *A.ovalifolius* and *C. cajan* were not. Yulianingsih and Arisoesilaningsih (2015) reported that *C. brevifolius*, *C. eragrostis*, *C. odoratus* and *C. strigosus* seeds were able to germinate, whereas *K. monocephala* seeds were not able to germinate up to 17 days after sowing. *Paspalum conjugatum* was a plant species that always grew, while *Eleusine indica* was not able to germinate (Rahma and Arisoesilaningsih, 2015).

Selection of plants used in revegetation for reasons of having high abundance in the post-mining site, but not all species successfully grows with hydroseeding technique. *Poaceae*, *Leguminoseae* and *Cyperaceae* on post-mining site grow on feces of buffalo that come to graze. Improvement of vegetation formation and stabilization of steep slopes due to mining requires mixture of seed, fertilizer, and mulch binders in hydroseeding technique (Brofas and Varelidas, 2000). However, the composition of the optimum mixture of hydroseeding mulch remains unknown.

Buffalo feces were used as model of hydroseeding mixture. Buffalo feces are strong textured, grip the post mining land and steady on exposure of rain. Imitation of mulch composition of the buffalo feces was conducted by making several variations of mulch to determine optimum mulch that indicates most significant contribution to germination of seeds.

Materials and Methods

This study was conducted from March to December 2015 in the Glasshouse of the Department of Biology, Brawijaya University. Data analysis was performed at the Laboratory of Ecology, Department of Biology, Faculty of Mathematics and Natural Sciences, Brawijaya University. This study used 100 seeds per pot for each plant species, whereas *Crotalaria pallida* that used 10 seeds and *Cajanus cajan* that used five seeds per pot. Mulch one (control) was made of buffalo feces plus water. Mulch two, three, four and five were composed by mixture of galam barb, cocopit, humid acid, LMO (local microorganism) and water, but containing different adhesive. Mulch six and seven were composed by mixture of sawdust, cocopit, LMO, goat compost, leaf compost, water and adhesive.

Post coal mining soil was collected from coal mining company in South Kalimantan. pH, conductivity and content of organic matter of the soil were observed before growing the plants. Germination of seeds was detected by sowing seeds on mulch that applied in post coal mining soil at plastic bag (4.5 x 3 cm). The plastic was filled with post-mining soil on five centimeters (± 100 g) and plus mulch under two centimeters (± 20 g).

Germination seed was observed at 15 days. Abiotic factors such as temperature, humidity and light intensity were weekly observed. The data were tabulated in Ms. Excel and analyzed using multivariate analysis.

Results

Seed germination of each species in seven mulch used for this study showed different results (Table 1). Seeds of *Leguminosae* group had higher percentage of germination and rapid germination time compared to *Poaceae* and *Cyperaceae* groups (Figures 1 and 2). Germination is the start of the process of metabolism and growth characterized by the emergence of the radicle to penetrate the seed coat. *Leguminosae* is classified in epigeal germination. Epigeal germination begins with water uptake by dry seed imbibitions followed by the development of the embryo.

During germination, cotyledon above the soil surface provides nutrients to the growing point (Savage et al., 2006). The highest germination percentage (56.7%) was observed for mulch two with the addition of *Cajanus cajan* seed at 8 days after sowing, The lowest germination percentage was observed at mulch four that was equal to 16.7% at 10 days after sowing (Figure 3).

Seeds of *Crotalaria pallida* showed the greatest germination percentage (39.4%) at mulch two in 3 days after sowing and the lowest (13.3%) was for mulch seven at 3 days after sowing. Both species of *Leguminosae* group were able to germinate in the mulch with the fastest time of germination was 3 days after sowing and the longest was 10 days after sowing.

Table 1. The percentage of seed germination of some species of *Poaceae*, *Leguminosae* and *Cyperaceae* in each mulch added on soil of post coal mining land.

No	Species	Germination Rate (%)							Time of Germination (days after sowing)*						
		M1	M2	M3	M4	M5	M6	M7	M1	M2	M3	M4	M5	M6	M7
1	*C. pallida*	16.7	39.4	26.1	23.9	17.2	30	13.3	4	3	6	3	3	3	3
2	*C. cajan*	53.3	56.7	26.7	16.7	26.7	36.7	23.3	3	8	5	10	10	4	7
3	*K. monocephala*	1.8	-	0.2	-	-	0.4	0.8	17	-	28	-	-	15	15
4	*P. conjugatum*	13.0	6.3	8.0	1.7	1.4	5.7	10.2	10	18	9	12	12	14	14
5	*D. sanguinalis*	7.0	0.4	3.4	-	0.7	3.2	14.3	12	3	12	-	7	14	11
6	*E. indica*	3.8	0.1	0.7	0.1	0.1	0.7	0.6	10	28	16	13	28	14	13
7	*Polyculture*	6.5	5.7	7.6	5.6	6.2	6.8	10.8	4	3	3	3	4	16	6

Remarks: * until 30 days after sowing, M=Mulch.

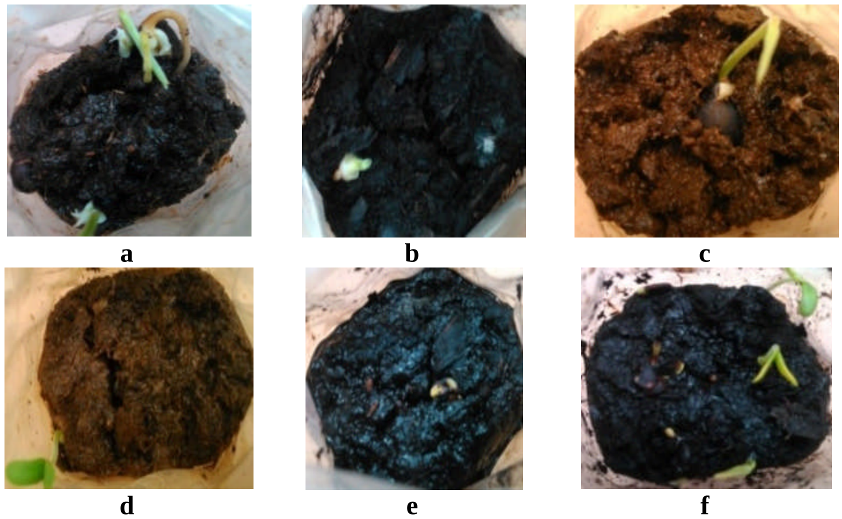

Figure 1. Germination of *Leguminosae* seeds in different mulch 3 days after sowing. Notice : a. CcM1, b. CcM3, c. CcM5, d. CpM1, e. CpM3, f. CpM5, Cc = *Cajanus cajan*, Cp = *Crotalaria pallida*. Scale : 1 cm.

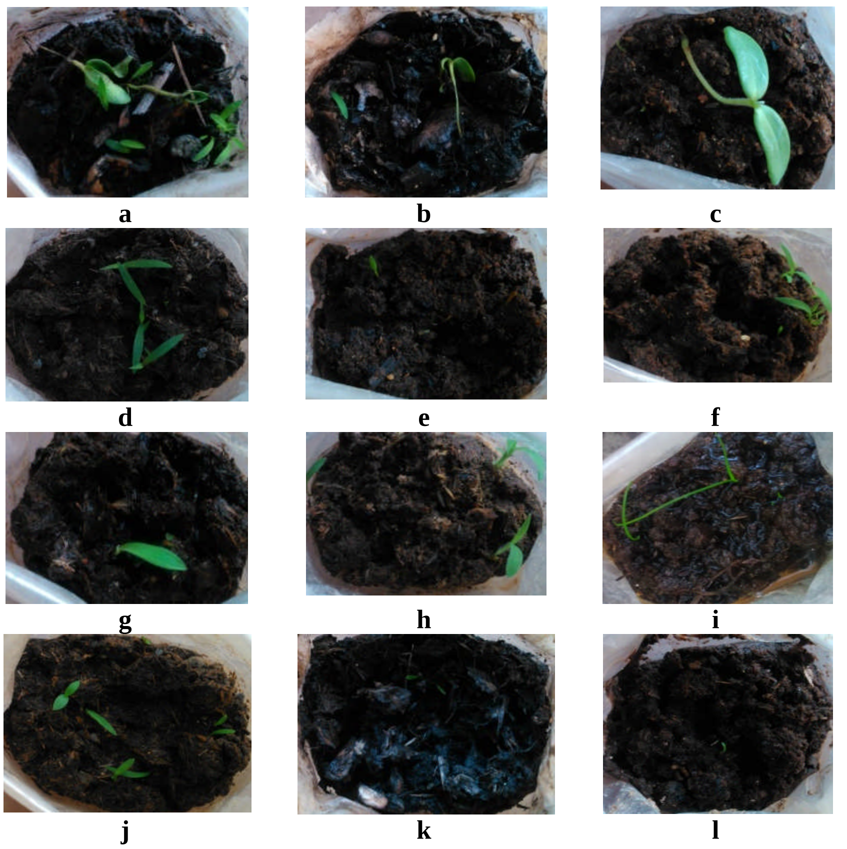

Figure 2. Germination of *Cyperaceae* and *Poaceae* seeds in different mulch 15 days after sowing. Notice: a. PoliM4, b. PoliM5, c. PoliM7, d. PcM1, e. PcM6, f. PcM7, g. DsM1, h. DsM7, i. KmM3, j. EiM1, k. EiM4, l. EiM6, Poli = Polyculture, Pc = *Paspalum conjugatum*, Ds = *Digitaria sanguinalis*, Km = *Kylinga monocephala*, Ei = *Eleusine indica*. Scale : 1 cm.

Results of this study were quite different from previous research reported by Baiti and Arisoesilaningsih (2015) that the seeds of *C. cajan* were not able to germinate due to microbial contamination.In this study, *C. cajan* had the highest percentage of germination. Mulch played an important role as a source of nutrients for germination and plant growth. In addition, mulch maintains soil moisture and suppresses the growth of weeds and plant diseases (Brooks et al., 2011).

Poaceae species used in this study were *Paspalum conjugatum*, *Digitaria sanguinalis* and *Eleusine indica*. Of the three species, *Paspalum conjugatum* and *Eleusine indica* were able to germinate in the seven mulches used for this study. The highest germination percentage of *Paspalum conjugatum* (13%) was in control at 10 days after sowing, and the lowest (1.4%) was in the mulch five at 12 days after sowing. *Eleusine indica* seeds were able to germinate with the highest percentage of germination (3.8%) was at 10 days after sowing, while the lowest (0.1%) was at 28 days after sowing.

Digitaria sanguinalis seeds were able to grow at six mulches applied to the post-mining soil and did not grow on mulch four to 30 days after sowing. *Kyllinga Monocephala* seeds were able to germinate in four of the seven mulches applied, namely mulch one, three, six and seven with the highest percentage of mulch one (1.8%) at 17 days after sowing. The lowest (0.2%) was observed at mulch two at 28 days after sowing. Seeds planted in polyculture were able to germinate at all mulches. The highest germination percentage (10.8%) was in mulch seven at 6 days after sowing, and lowest (5.6%) was in the mulch four at 3 days after sowing.

Germination of the group belonged to the *Poaceae* and *Cyperaceae* hypogeal germination. During germination, the cotyledons are underground providing nutrients to all the growing point of germination (Savage et al., 2006). Low percentage of germination might be due to several factors such as the level of maturity of seeds/seedlings, seed size and dormancy.

Other factors such as inhibitor compound either in the seed or in the surface of the seeds, the availability of water, oxygen, light and temperature optimum germination, are proposed (Rofik and Murniati, 2008). Of the six species used, the species that were not able to grow was *Kyllinga monocephala* in mulch two, four, five and *Digitaria sanguinalis* in mulch four, while other species grew in all mulches.

Inability of species to grow was thought to be caused by insufficient seed and mulch for germination. Further research regarding determination of factors affecting germination percentage and germination time in some species, is encouraged. Germination common problems occur due to competition between the organism to obtain resources and nutrients to grow and thrive. The number of plants that grow is affected by competition in the phase seedling (Gopal and Bhardwaj, 1979).

The highest variation coverage of the CcM1 (*Cajanus cajan* in mulch 1) and PoliM1 (polyculture in mulch 1) was 100% of 6 days after sowing until harvesting. Coverage of the plants was observed in all treatments. The highest closing (100%) was observed for *Crotalaria pallida* on CpM1 at 28 days after sowing, and the lowest (7.4%) was on CpM2 at 28 days after sowing. However, at 56 days after sowing the percentage of closing of all plants was 100% (Figure 3).

On the *Cajanus cajan* species, the highest closing (100%) was CcM1 at 6 days after sowing, and the lowest (67%) was CcM7 at 56 days after sowing. In the group of *C. cajan* the closing percentage of all plants was 100% at 56 days after sowing except CcM7. The highest percentage of closing (100%) of *Kyllinga monocephala* species was on observed for KmM1 at 42 days after sowing, and lowest (0.8%) was for KmM5 at 56 days after sowing. KmM1 was the only one having the closure of 100% up to 56 days after sowing. The highest closing (100%) of *Digitaria sanguinalis* species was for DsM1 at 21 days after sowing, and the lowest (28.3%) was for DsM4 up to 56 days after sowing.

All groups of *D. sanguinalis* species had 100% closure up to 56 days after sowing except DsM2 and DSM4. The highest closure (100%) in the group of *Eleusine indica* species was on EiM1 (at 42 days after sowing, and the lowest (25%) was on EiM5 at 56 days after sowing. At polyculture planting, the highest closing (100%) was observed for PoliM1 at 21 days after sowing, and the lowest (85%) was on PoliM2 at 35 days after sowing,. However, all treatments could achieve closure of 100% up to 56 days after sowing.

In the treatment of polyculture, *Leguminoseae* group was predominant species that dominated during germination and plant closings accounted for most. *Leguminosae* can inhibit the growth and development of the reeds (Irwanto, 2006). In addition, the bean crop of *Leguminosae* contributes in the form of organic matter, nitrogen and phosphorus to the soil if it is dead or deliberately suppressed.

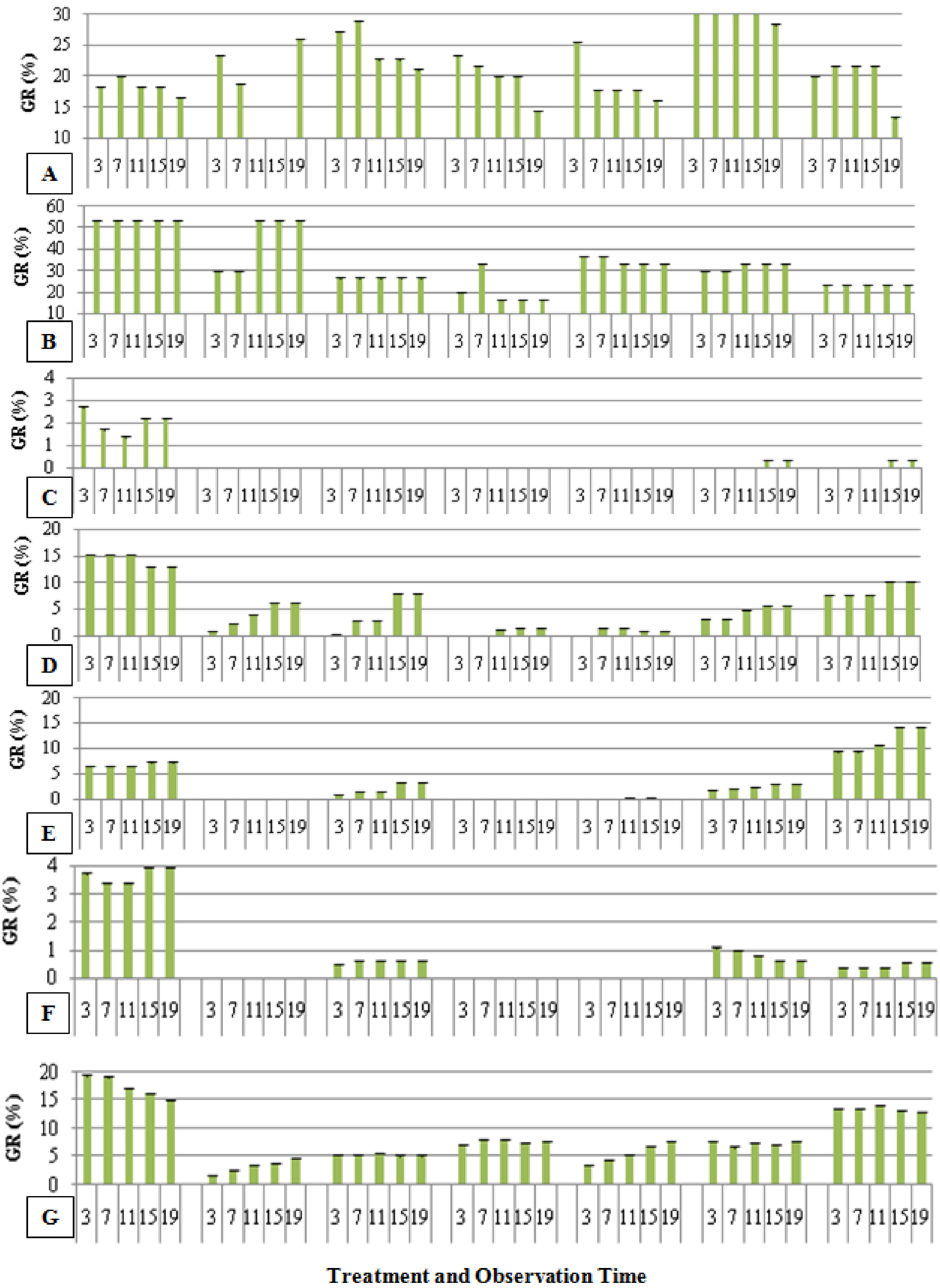

Figure 3. The percentage of germination of each species in seven mulches from 3 to 19 days after planting mulching. Description: A. The percentage of germination of *C.Pallida*, B. The percentage of germination of *C.cajan*, C. The percentage of germination of *K. Monocephala*, D. The percentage of germination of *P.Conjugatum*, E. The percentage of germination of *D.Sanguinalis*, F. The percentage of germination of *E.Indica*, G. The percentage of germination in seven mulches polyculture. GR : Germination Rate

Conclusion

Species used in this study were able to germinate in the mulch added to the post-mining land, except *Kyllinga monocephala* on mulch two, four and five and *Digitaria sanguinalis* on mulch four. The highest percentage of germination was *Cajanus cajan* (56.7%) on the mulch two with germination time at eight days after sowing. The lowest germination percentage was shown by *Kyllinga monocephala* at all mulch types (up to 30 days after sowing). The optimum compositions of mulch suggested to accelerate the revegetation were mulch two (pH 7.06 and 59% organic matter) especially for Leguminosae, and mulch seven (pH 6.8 and 47% organic matter) especially for Poaceae and polyculture.

Acknowledgments

This project was supported by Competitive Grant Program of the Faculty of Mathematics and Natural Science, Brawijaya University. The authors thank Purnomo and Amalia of Laboratory of Ecology Department of Biology for their valuable laboratory assistance.

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