CHAPTER 5

Discussion

5.1 Comparing species in the field:

5.1.1 Germination, establishment and MLD across all species in the field:

Candidate species suitable for direct seeding must have acceptably high germination percent (small number of seeds need to be sown), rapid germination (i.e.; shorter MLD which reduce the time for seed predation and maximize the time seedling growth before dry season) and high seedling establishment (Lamb, 2011).

Seed characteristics may explain the differences in species responses in the field. *A. xylocarpa* and *S.oleosa* which both achieved the acceptable level for direct seeding in the field study both had large seeds with intermediate or medium seed size, along with moderate to thick seed coats.

Also, both of them showed epigeal germination are which is considered to be fast and synchronous than slower cryptogeal mode (Vazquez-Yanes & Orozco-Segovia, 1993).

For example, it is known that species with photosynthetic cotyledons (= PEF) are capable of using light as an energy source earlier than those with reserve cotyledons (=CHR primarily) (Amritphale & Sharma, 2008). Thus, photosynthetic cotyledons could be more advantageous in high-light environments. Indeed, these cotyledons are often found associated with open vegetation such as the grassland, forest edge and gaps. On the other hand, reserve cotyledons, which can provide resources to support seedling energy demands for a relatively longer period, are of common occurrence in low-light environments characteristic of closed vegetation exemplified by moist tropical forest (Amritphale & Sharma, 2008).

We can see from our experiment *S. oleosa* seedlings morphology showed PEF type germination, and *A. xylocarpa* showed reserve cotyledons type CER. Both of them

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established themselves in a barren site. So, the relationship between cotyledons and vegetation type is not yet clearly indicated. Indeed, a high degree of overlap between the first two cotyledon functional types is also quite likely because some species germinating in one type of vegetation may persist in the other. Developing data banks for functional morphology of seedlings in different plant communities along with those for other seed/seedling traits such as seed and seedling size and tolerance to abiotic/biotic stresses would assist in constructing appropriate models for biodiversity management.

Tunjai and Elliott (2011) showed that species with significantly higher germination possess medium to large seeds, which are round or oval in shape. These seed traits were associated with moderate to thick seed coat which consequently seedling establishment. These criteria predicted that *A. xylocarpa* and *S.oleosa* would be successful for direct seeding in this study. Their percent germination and establishment were significantly higher and MLD'S were significantly shorter, compared with other species (Table 4-1). Shankar (2006) reported that large seeds carry with them greater food reserves, giving very young seedlings a greater chance of survival. In this study, small-seeded species percent germination, MLD and percent establishment were insufficient for them to qualify as suitable for direct seeding. Large seeds appear to have greater tolerance of stresses, since higher resources can be allocated to tolerate particular stresses such drought or shade (Coomes & Grubb, 2003; Helene C. Muller-Landau, 2010) whereas small-seeded species cannot tolerate stresses because food resources within the seed are limited.

In this study, the species with high percent germination also had short dormancy. Large size is also associated with avoidance of seed predation (Nepstad *et al*. 1996; Hau 1997). Moles and Westoby (2006) reported that, during the juvenile stage, seedlings germinating from larger seeds generally, exhibit higher survival and seedling recruitment rates. Even within species, larger seeds tend to have higher germination and seedling survival rates (Cicek & Tilki, 2007; Eriksson, 1999; Manga & Sen, 1995). However, thick seed coats can delay germination (Tunjai, 2005), so pre-sowing treatments are often necessary to shorten dormancy resulting from a hard seed coat. In

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this experiment, a pre-sowing treatment was used for the hard-coated seed species. This accounts for the shortened dormancy recorded for the hard-coated species (Table 4-1).

5.1.2 Comparing treatments in the field:

One possible explanation for the lack of significant differences in the effectiveness of the various treatments tested may be that, insufficient amounts of the substrate amelioration substances were applied (Table 4-2). Also, while experiment plot was set up that time may be the rain washed out most of the treatments, as it was heavy rainfall at that time (Figure-3.2). So, it would be suggested to prepare the site before started the rainy season, and at the 2nd or 3rd week of the rainy season it would better to put the seed.

In this experiment, the success of *A. xylocarpa* might be due to the fact that it is a legume, which are notable for being able to fix nitrogen (Cervantes, Carabias and Vazquez-Yanes, (1996); Garg, (1999); Siddique *et al*., (2008). This enables leguminous species to survive on degraded areas with excellent growth performance (Engel and Parrotta, 2001). Furthermore, the final germination percent of *A. xylocarpa* in the field was increased by scarification and thus seed coat dormancy had been overcome (Tunjai, 2005).

The final germination percent and establishment of *S. oleosa* in the field were high enough to allow this species to be considered suitable for direct seeding (Table4). Temperature might be an important factor for this species to overcome dormancy, because seedlings of *S. oleosa* are light-demanding [www.worldagroforestrycentre.org]. In the field site, there was no canopy cover, so light-demanding species can do well in a lignite mine area. Also, the habitat preference of this species is dry, mixed, deciduous forest often rocky, loamy or gravelly, which matched the field soil characteristics (Appendix B, Table B-1).

E. cumini, *G. arborea* and *F. racemosa (*Table 4.1) in this study, did not meet the acceptable standard for direct seeding, as they showed low percent of germination, as well as long MLD (Table 4-1).

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E. Cumini may have had low germination due to storing the seeds too long after collection. They were sown in the field after 43 days storage. FORRU (unpublished data) recorded a germination percent for this species of 96%, with exposure to sunlight (the same pre-sowing treatment as used in this experiment). So it is likely that seeds lost viability during storage and that this species is recalcitrant. *Eugenia* bears fleshy berries dispersed by animals, which is typical of late succession species (Schmiddt, 2007; Jordona, 2000). Such species generally produced small, slow growing seedlings [Figure 4.8, 4.9 & 4.10] which are quiescent until suitable conditions are created (Fermer & Thompson, 2005; Whitmore, 1989).

In the field, *G. arborea* should be considered carefully, because it had percent germination about 38% and 39% in biosolids+fertilizer and biosolids treatments respectively with relatively short MLD [Figure 4-1 (a, b) & Figure (a, b)]. Their percent establishment was low (<10%), which is not acceptable for direct seeding. This might have been due to the compacted nature of the mine substrate restricting drainage and oxygen penetration to the roots (Allen et al., 2007). However, *Gmelina arborea* does very well when planted out as seedlings into mine sites. The tree in this photo just 2 year old at Mae Than mine (FORRU, unpublished data).

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Figure 0-1: Field Plot at Mae Than Mine (Two years old).

Lastly, *F. racemosa* was unacceptable for direct seeding because of low percent germination and long dormancy [Figure 4.5 & 4.7]. Fig seeds are tiny. They do not contain sufficient food resources to support early seedling growth, which probably makes them unsuitable for direct seeding (Kuaraksa & Elliott, 2013).

5.1.3 Effect of treatment on seedling growth in the field:

Surprisingly, treatment had no significant effect on the mean RCD, mean Height and relative growth rates of five species, which was measured one year after sowing the seed. The only difference found in *A. xylocarpa* in all applied treatments; negative value in their RGR height and RGR crown width (CW) it's due to this species most of the time eaten by cattle groups. Cattle, Goat, sheep and other livestock can completely prevent forest regeneration by browsing on young tress. Careful livestock management can therefore, have been beneficial effects for forest restoration (FORRU, 2008).

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Though, in the field study *S.oleosa* was not eaten by cattle group. The probable reason might be *S. oleosa* contains miscellaneous poison or repellent which might creates problem to digestion for cattle (http://plants.jstor.org/upwta/5_56). So, in future it may be useful to choose cattle resistance species to make the forest restoration project successful.

In addition, poor quality of soil (lack of essential nutrients and compaction; (Appendix B, Table.1) might be a major factor that cause slow growth rate of most of the species except *G. arborea* (Pioneer species) [Figure 4.8, 4.9 &4.10]. Before planting out time in the nursery, for pioneer species mean saplings height should be >30cm and for climax species>50 cm [FORRU, 2008]. In this field trial, *S.oleosa* & *A. xylocarpa* growth rate was showed accepted growth rate compare to nursery growth rate which was trial in forru nursery in previous time (Figure 4.2.4 a-e). *E .cumini* and *F. racemosa* growth rate was very slow which made them unsuitable for direct seeding on mine rehabilitated site. The reason behind is the higher pH range (>8.5) in the soil which is alkaline in nature. It can cause soil infertility and limit microbial activity (Allen et al., 2007). Thus, it can effect on plant growth in this substrate.

Also, soil physical properties refer that increasing bulk density, poor aggregation and textures that are too sandy or clayey. It is founded in our soil report, soil type was sandy loam, sandy clay loam & clay loam [Appendix B, Table B-2]. A soil with high bulk content generally has high clay content, which is too dense to contain enough space to allow oxygen to diffuse through soil and keep it aerated. Also, that soil report found the important elements of the soil was very low which also responsible for dwarf seedling for some species [Appendix B, Table B-1]. So, organic amendment of these soils recommended. However, analyzed soil contained high P, which resulted in Zn deficiency which also can lower the soil fertility. Zn, Cu, Mn and other materials are necessary as micronutrients. As in field trial pH was high which lower the soil micro nutrients level as well [www.ipni.net]. Moreover, proper ratios of Ca and Mg were also higher in the tested soil [Appendix B, table.1]. High ratio can inhibit the plant growth, so the ideal Ca: Mg ratio referred as 20:1 (Allen et al., 2007).

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5.1.4 Suitability Score for the species in the field:

The suitability score was calculated from percent establishment and growth performance by the middle of the 2nd rainy season after sowing (Table 4.5). Species with suitability scores exceeding 40 would be excellent candidate species for direct seeding; *S. oleosa* and, *A. xylocarpa* were suitable for direct seeding as they got suitability scores above 40%. All of them should be sown in the beginning of the rainy season which is also a critical point for species choice and appropriate timing.

The recommended two species are suggested not only because they are common species throughout the region, but also for conservation of common species is important for many aspect. They can play particularly important roles in ecosystems including dispersal, pollination as well as maintain food webs (Gaston, 2010; Sekercioglu, 2006).

As in this study framework tree species used. So they must rapidly capture degraded sites by growing fast and developing dense and spreading canopies. Also, framework tree species provide resources such as edible fruits or seeds, nectar, roosting or nesting sites (FORRU, 2000).

5.2 Comparing species in the nursery and effectiveness of treatment:

In this trial seasonal tree species seed used at the end of the rainy season. Also in the nursery study, try to find out species name by doing some germination test which can be adaptive to mining soil; at the same time treatment effectiveness. Percent germination of 4 species out of 8 species trialed in nursery exceeded 35%, which is acceptable for nursery production of native trees for forest restoration project (Elliott *et al*., 2002).

Consequently, large seeded species *A. xylocarpa*, *S. pinnata*, *I. malayana* and small seeded but hard seed coat species *C. spathulifolia* are recommended for field trial; as their percent germination achieved above 40%. Except *A. xylocarpa*; *S. pinnata*, *I. malayana* and *C. spathulifolia* MLD's (>180 days) were high during nursery trial. It is reported that many temperate species typically stay dormant over winter period (Schmidt, L. 2000), as the trial was set up at the end of the rainy season. Whereas, the

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result from FORRU (unpublished data) found that pre-sowing treatment can help these species e.g.; *I. malayana*, *S. pinnata* and *C. spathulifolia* to overcome MLD's.

So, it will be suggested for *I. malayana*, *S. pinnata* and *C. spathulifolia* species to use tested pre-sowing treatment which help them to overcome MLD and it could be an option to test with the trial treatments where it found higher germination during this study period. At the same time as they were orthodox seeds, so sowing time should be followed rainy season to get better result in the field.

A. pavonina germinated one month after sowing in the nursery, but percent germination was very low [Figure 4.11c]. The seedlings that germinated not survive. It has been reported that the best temperatures for germination of *A. pavonina* seeds is 35°C (Zpevak et al.; 2012); while temperature in the nursery was 24°C (Figure 3-2). So, it would be better to test this species in the nursery during May-June, while temperatures reached that point, also pre-sowing treatment of seeds should follow the overnight soaking of seeds in hot water (70°C) which gives good result around 75% (FORRU, data base, Unpublished data).

On the other hand, *S.oleosa*, *G. arborea* and *F. racemosa* percent germination was very low (10%) in every treatment which were tested. It may be possible for percent germination of S.oleosa to show poor performance due to clean the seeds with water before sowing the seeds. It might be washed out complete enzymes in the seed. Enzymes are required for germination along with any germination inhibitors (Bradbeer, 1988). Also previous nursery data from FORRU also found % of germination increased by using pre-sowing treatment sun & shade.

For, *G. arborea* it has been found that by using pre-sowing treatment such as soaking in the water for 2 nights and sun, their percent germination reached 95% and 83%; MLD were 55 and 25 days (FORRU, data base, Unpublished data).

In case of this experiment Pre-sowing treatment was also followed sun but showed poor germination and long MLD. The cause may be moisture and temperatures were not

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suitable to germinate for this pioneer species, as most tropical lowland species require temperatures of 20°C or more for germination to proceed (Schmidt, 2000).

F. racemosa also showed lower percent of germination, but they showed significantly higher germination in biosolids treatment. Possibly the organic matter influenced on their germination. However, their lower percent germination made them unsuitable for nursery production.

5.3 Possible practical application and future work:

The objectives of this study were to see the effectiveness of direct seeding for forest restoration in opencast lignite mine by framework species. Though more species need to be tested systematically, especially with the large seeded species. For certain suitable tree species, direct seeding could offer a cost-efficient alternative to out planting nursery raised trees for forest restoration project (Wood and Elliott, 2004).It can clearly seen that it was two studied species named *A. xylocarpa* and *S.oleosa* which were capable themselves to establish themselves in this harsh condition [Table 4.1.], also for *I. malayana*, *S. pinnata* and *C. spathulifolia* could be trial in the field study site.

Direct seeding save the cost compare to nursery raised seedlings for forest restoration in previous research (Tunjai,2005). However, in this experiment it was little bit higher. Study site soil required soil conditioner, as the soil condition is very poor (Appendix-B, Table-1). It increased the costs in lignite mine Lampang, Thailand.

Further research should be carried after soil was managed properly on this mine area; as it is not well aerated and do not have proper nutrition to support seedlings for their well growth. Also it has found on this study, sudden water logged condition which created problems for plant. As the soil was compact, so it should be considered to improve the condition.

Furthermore, the treatments did not have any significant effective, but the study site required top soil replacement. So, top soil application should be considered before starting any restoration work, so that plant get benefits from site.

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The top soil replacement worked very well at the Muang Poon mine (FORRU, unpublished data).

Figure 0-2: Two year old plot at Muang Poon mine, Planted with saplings on 30 cm of dumped top soil.

According to soil report it can assume that more acidic materials should be applied to neutral the alkalinity nature of the soil. At the same time, development of biological process like influences of mycorrhizal symbiosis on plant growth on mine site. In that case mycorrhizal fungi may contribute to plant establishment on this site by supplementing the nutrient absorption capacity of root systems and improving the soil structure. Revegetation may therefore be aided by a combined plant/ microbe treatment (Shetty *et al*., 1999).

As in the study site were undulated and compact as well, but they were not loosen by any dozer or excavator. So an excavator can be used to level dumped topsoil piles without causing any compaction. Salvaged native soils and other materials can be used for mine soil construction. Mixing can accomplish by hauling and dumpling materials, also by lightly grading surface (Skousen *et al*., 2011). Weathered sandstone and selected un-weathered materials can be used to improve soil site; especially they would be acted

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as a growth media. Weathered sandstone will generally have pH of 4.5-6, so they should be applied 4 feet in thickness which will restore land capability and support forest growth and diversity at pre-mining levels. It has been reported, on West Virginia, America has formed a mine soil that supports good tree growth and has good colonization of native plants after two years. Mine soil pH is maintaining 6.0. Compared with weathered sandstone, un-weathered sandstone on the same mine site showed poor tree growth, as their ph level was high (pH=8) (Skousen *et al*; 2011). It was same as our study site pH level. So, lowering soil pH must be done before restoration. Elemental S or acidic materials can be used in certain amount to lower the soil pH [www.ipni.net]. Moreover, the study site soil was very poor [Appendix B, table.1]. So this table will give us the idea about types of problems addressed by soil amendments and solutions.

At the same time, seeds that have large (>0.1g dry mass), spherical size with medium moisture content (36-70%) (Tunjai and Elliott, 2011) have to apply on the ground. Large seeds have large food reserves so that they can survive longer than smaller seeds and produce robust seedlings tree species. Published accounts of direct seeding can successfully established by pioneer species (Engel and Parrotta, 2001),because their seedling grows rapidly. At the same time climax forest species can also successfully established by direct seeding, as they have large seeds and energy reserves (Hardwick, 1999; Cole *et al.*,2011; Sansevero *et al*., 2011).

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