Introduction of a vegetation–friendly bio-based soil binder

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ABSTRACT: Desertification and vegetation growth have been a major area of interest for sustainable development. Generally, the vegetation growth is affected by several factors, including soil density (pore spaces) and soil-water characteristics. The soil water retention characteristic and water delivery to plant roots are crucial for seed germination and following plant growth. Plants require a small amount of water for their metabolic purposes; however, the most of moisture is lost through transpiration. Furthermore, lower water holding capacity and excessive drainage of water of sandy soils can impede the plant growth. In study, a vegetation-friendly soil strengthening binder is introduced to provide soil strengthening as well as vegetation improvement effects. Microbial biopolymer has been mixed with soil in hydrogel phase to enhance the water retention of soils and to promote vegetation growth in the same medium. In-situ soil, and cultured soil were used for experimental verifications.

Keywords: Biopolymer, Bio-soil, Vegetation, Water retention, Anti-desertification

1 INTRODUCTION

The development of human civilization paradoxically involves disturbance of nature, especially soil including excavation, artificial ground mixing and substitution, land degradation and erosion in geotechnical engineering aspects. Not only environmental destruction but also human activities such as grazing, deforestation, burning cultivation field accelerates land degradation and accompanying geotechnical engineering problems (Kettel 1996; Wang et al. 2006). Nowadays, land degradation and desertification become a serious threat to human beings (Chang et al. 2015). Eroded aeolian dusts can absorb contaminated materials or heavy metals such as mercury, cadmium, chrome, and lead, which can cause serious respiratory disease (Kar and Takeuchi 2004). Moreover, the annual aeolian yellow dust originated from the arid regions of West China is reported to occur acid rain in Far East countries, especially in Korea. Thus, soil erosion and land degradation are not specific issues for a single nation only but becomes a global concern. The most common countermeasure approach for land degradation and desertification is afforestation or reforestation (Lal 2001). However, numbers of massive afforestation projects are reported to be insufficient due to the lack of geotechnical, especially ground treatment considerations (Cao 2008; Veste et al. 2006).

Recently, microbial biopolymers have been introduced and attempted as a new soil strengthening binder due to their high-viscous hydrogel formation and hydrogen bonding characteristic with clayey particles (Chang et al. 2016; Chang et al. 2015; Smitha and Sachan 2016). In addition, biopolymer treatment shows promising potential to be applied as an environmentally friendly soil stabilization material for soil erosion prevention and anti-desertification purposes (Chang et al. 2015; Orts et al. 2007; Qureshi et al. 2017). In this study, the vegetation growth behavior of biopolymer-treated soils is investigated through laboratory approaches to propose a vegetation-friendly soil binder for sustainable geotechnical engineering practices.

2 MATERIALS AND METHOD

2.1 *Materials and methods*

Three soil types (culture soil for planting; in-situ soil from *Seosan*, Korea; and sand – in-situ soil mixtures) are used for laboratory program. Particle size distribution curve of *seosan* soil is shown in Fig. 1. Mixed soil mixtures were prepared by mixing *jumunjin* sand and in-situ soil within 1:9, 2:8, 3:7 and 4:6 ratios in mass. Biopolymer concentrations of mixing were fixed as 0% (untreated), 0.25%, 0.5% and 1% (ratio to the mass of soil) for each soil. Three different vegetation types (perennial ryegrass (PR), Kentucky blue grass (KB), and tall fescue (TF)) were bedded on soil specimens (Table 1).

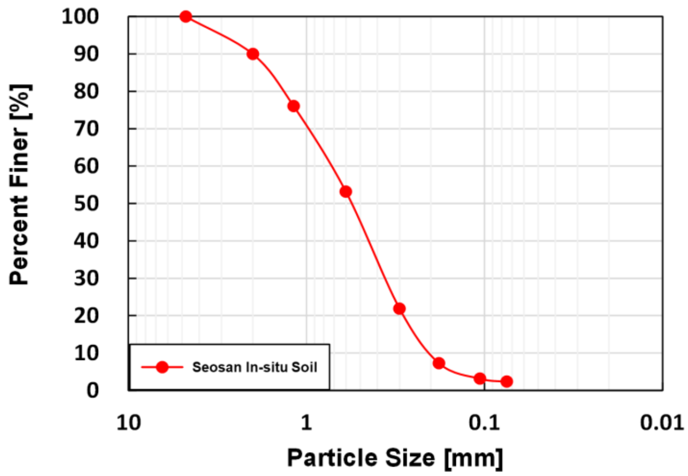


Figure 1. Particle size distribution of in-situ *Seosan* soil (USCS: *SW*).

Table 1. Experimental condition of soil type, biopolymer concentration and applied plant type.

Soil type		Biopolymer Concentration [%]			
		0	0.25	0.5	1.0
Culture soil		PR	PR	PR	PR
		KB	KB	KB	KB
		TF	TF	TF	TF
In-situ (*seosan*) soil		PR	PR	PR	PR
		KB	KB	KB	KB
		TF	TF	TF	TF
Mixed soil (Sand:In-situ)	1:9			KB	
	2:8			KB	
	3:7			KB	
	4:6			KB	

3 TEST RESULTS

3.1 *Effect of biopolymer content on vegetation growth*

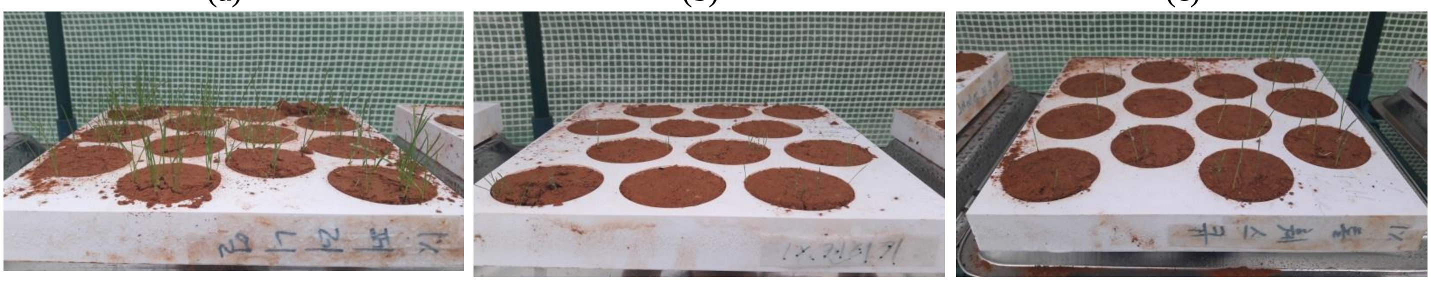
To investigate the biopolymer treatment effect on the vegetation growth behavior, number of germinated seeds and average height of sprouts have been monitored with time. Maximum average height reached 10.54 $\times 10^{-2}$ m and 5.8 $\times 10^{-2}$ m in untreated culture soil for TF and KB, respectively, while PR shows the maximum average height of 10.5 $\times 10^{-2}$ m in 0.25% biopolymer-treated culture soil. In all cases, the average height of all grown plants in culture soil become higher than those grown in in-situ soil (Fig. 2).

Meanwhile, the relationship between biopolymer concentration and number of germinated sprouts is not proportional. As shown in Fig. 3, 0.25% biopolymer treatment condition shows the highest number of germinated seeds, while biopolymer concentration above 0.5% reduces the number of germinated sprouts, regardless of soil and vegetation types. However, biopolymer treatment method become invalidated at the cultured soil. Even biopolymer treatment makes the cultured soil become less germinated regardless of plant type.

3.2 *Optimal growing condition; ratio between sand and field soil*

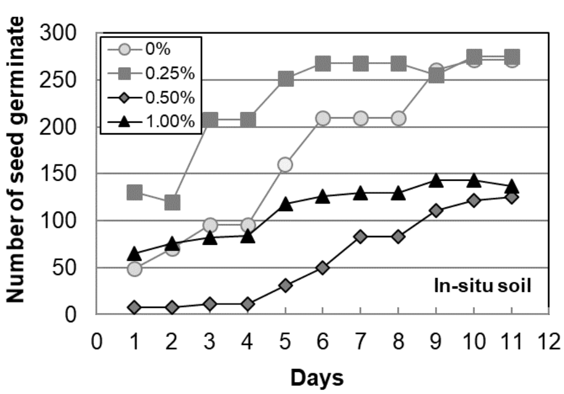
The soil composition effect for mixed soil is displayed in Fig. 4. For mixed soil, the mixing ratio between sand and in-situ soil at 1:9 and 2:8 (sand less than 20%) shows the less than 50 sprouts, while mixed soils with higher sand contents (3:7 and 4:6) show doubled seed germination efficiency. Thus, it can be implied that soil composition (coarse and fine contents) to be an important consideration for the vegetation growth performance of biopolymer-treated soils.

(a) (b) (c)

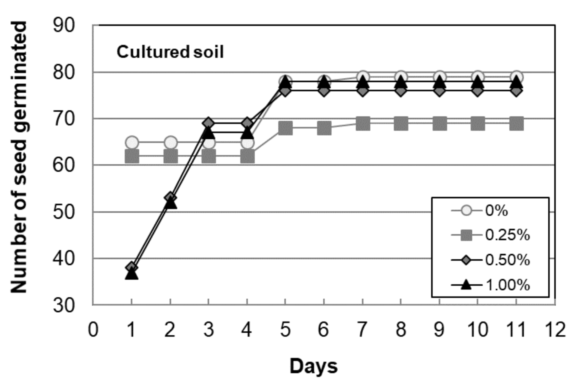


(d) (e) (f)

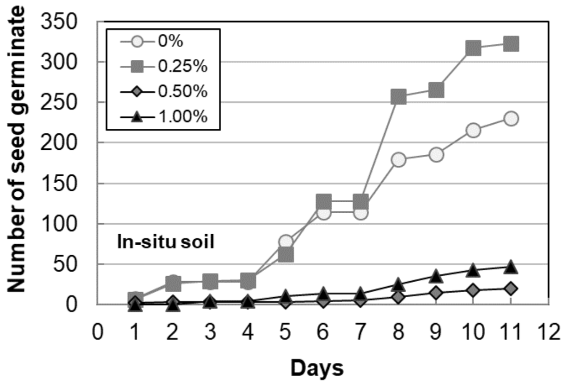
Figure 2. Comparison of average height of vegetation. Perennial ryegrass (a), Kentucky bluegrass (b), and tall fescue (c) in untreated culture soil. Perennial ryegrass (d), Kentucky bluegrass (e), and tall fescue (f) in 1% biopolymer-treated in-situ soil.



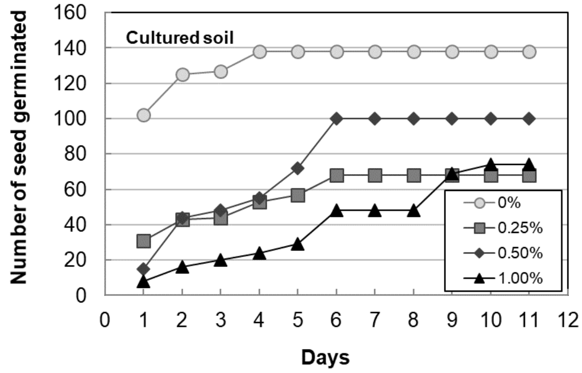
(a)



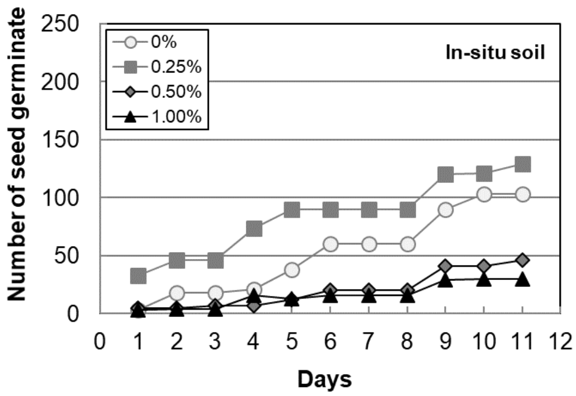
(b)



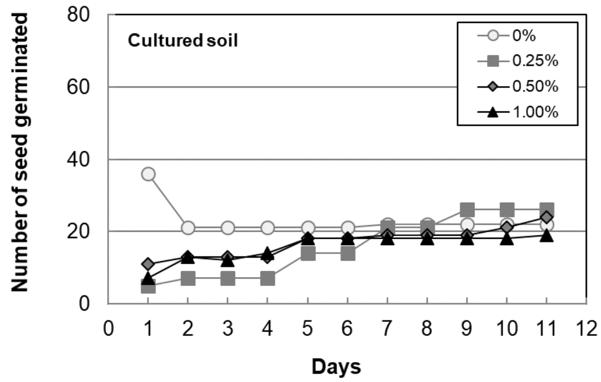
(c)



(d)



(e)



(f)

Figure 3. Comparison of biopolymer concentration. Perennial ryegrass seeds germination in In-situ soil condition (a) and in culture soil condition (b); Kentucky bluegrass seeds germination in in-situ soil condition (c) and in culture soil condition (d); tall fescue seeds germination in In-situ soil condition (e) and in culture soil condition (f).

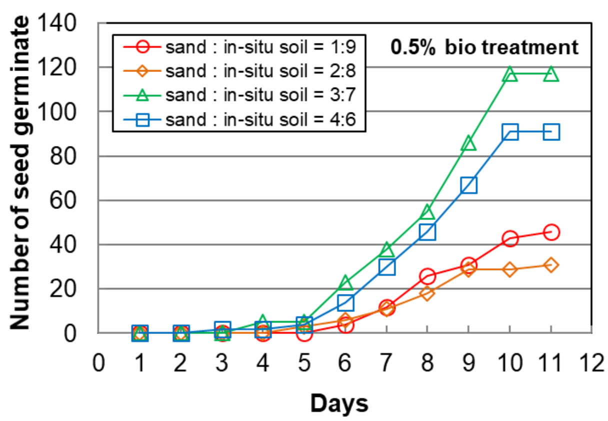


Figure 4. Mixture ratio between field soil and cultured soil does not affect to seed germination.

4 DISCUSSIONS

4.1 *Optimal plant type and biopolymer treatment concentration*

Although the average height of sprouts of TF is higher than that of PR, PR sprouts are overwhelmingly dense (higher number of germination) than any other plant types (Fig. 2). In other words, PR is evaluated to be the most appropriate vegetation type to be applied with biopolymer soil treatment from this study.

For in-situ soil condition, number of germinated sprouts shows the highest at 0.25% biopolymer concentration. However, vegetation growth in culture soil does not show a clear tendency (Fig. 3), while 0.25% biopolymer content does not significantly interrupt the vegetation growth in culture soil. In fact, the biopolymer treatment effect is expected to be less effective due to the presence of plentiful nutrients in artificial culture soil. Nevertheless, TF shows the best growing performance in 0.25% biopolymer-treated culture soil medium (Fig. 3f). Thus, in overall, 0.25% biopolymer content seems to be the most appropriate condition for soil mixing to ensure sufficient vegetation growth.

4.2 *Optimal Soil Condition for Enhancement of Seed Germination*

Seed germination seems to have a significant effect from the soil composition. For mixed soils (sand and in-situ soil), the number of germinated sprouts increase with sand content increase up to 30% of sand (Fig. 4). However, seed germination does not grow indefinitely with sand content increase, where 40% of sand shows lower number of sprouts compared to 30% sand. Thus, there should be an optimal soil composition for vegetation growth which renders optimal pore spaces for water, air supply and root penetration.

5 CONCLUSIONS

Nowadays, microbial biopolymers are becoming an emerging alternative for soil preservation in sustainability and environmentally-friendly aspects. The most distinctive characteristic of biopolymer treatment is its promising performance on satisfying both soil strengthening and vegetation promotion demands. Thus, biopolymer can be used as a soil binder for not only soil strengthening but also as a supplement matter to promote surface vegetation growth. In this study, the vegetation growth in biopolymer-treated soils have been investigated by considering 1) soil type, 2) biopolymer content, and 3) vegetation type. Indeed, artificial culture soil shows the best vegetation growth, while soil with appropriate coarse contents (around 30%) shows the most sufficient vegetation growth behavior among in-situ soils. For in-situ soil, 0.25% biopolymer content becomes the most appropriate condition for vegetation growth. Furthermore, among other vegetation types, perennial ryegrass shows highest germination ratio regardless of soil type. Thus, perennial ryegrass can be selected to be the main vegetation type for various biopolymer-soil site applications including afforestation and in-situ seed-spraying.

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